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Wisconsin Dept. of Natural Resources, Madison

Prepared for

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Volume 3:
Study Site Characteristics, Experimental Methods and Quality Assurance Program

Wisconsin Department of Natural Resources
Madison, Wisconsin
1983

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EVALUATION OF URBAN NONPOINT SOURCE POLLUTION MANAGEMENT IN MILWAUKEE COUNTY, WISCONSIN

VOLUME III

STUDY SITE CHARACTERISTICS, EXPERIMENTAL METHODS AND QUALITY ASSURANCE PROGRAM

By

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i.a

PREFACE

Volume III of this three volume final report submitted by the Wisconsin Department of Natural Resources (WDNR) to the Environmental Protection Agency is partial fulfillment of a grant entitled Evaluation of Urban Nonpoint Source Pollution Management in Milwaukee County, Wisconsin (Grant No. P005432-01-5). This project provided an evaluation of the characteristics, impacts, sources and management of urban stormwater pollution in Milwaukee. Volume III contains the Materials and Methods, Quality Assurance, and other supportive and ancillary material related to this project. This was a four year intensive study, continuing from July 1979 until June 1983. The U.S. Geological Survey (USGS) and the Southeastern Wisconsin Regional Planning Commission (SEWRPC), under contract to the WDNR, have contributed extensively to this project.

DISCLAIMER

This report has been reviewed by the Urban Nonpoint Sources Section, U.S. Environmental Protection Agency, Washington, D.C. The report does not necessarily reflect the views and policies of the agency, and no official endorsement should be inferred. Mention of trade names of commercial products does not constitute endorsement or recommendation for use.

ACKNOWLEDGEMENTS

A great many people have contributed both directly and indirectly to the successful completion of this project. An inclusive list of all contributors would be exhaustive. Although not everyone can be individually recognized, the authors wish to thank the staffs of the WDNR, USGS, SEWRPC, Wisconsin State Lab of Hygiene, and of the cities of Milwaukee and West Allis, Wisconsin. Additionally, numerous individuals have contributed extensively to this project and are appreciatively acknowledged below.

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VOLUME III

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CHAPTER I
INTRODUCTION

This third volume of the Milwaukee Urban Runoff Project report contains specific sample collection and quality assurance information. This information is important for a complete understanding of the field monitoring program. The results and conclusions presented in the other project volumes should be reviewed in consideration of this material. The procedures presented in this volume were based on past projects and on the experience gained during this current project. The quality assurance information addresses such things as potential sample contamination, cleaning procedures, and other important questions that were raised during the project. Many special tests were conducted to address these questions, and the results of these tests are presented in this volume. These test results also influenced the conclusions presented in the other volumes.

Detailed site descriptions are presented, including the procedures used to select the sites and to obtain the site characteristic information. A general summary of Milwaukee climatic conditions is also given to supplement the more detailed precipitation information presented in the earlier volumes. Sampling equipment and procedures are described, including recommendations for equipment modifications and trouble-shooting guides that were developed during this project. Special tests are explained that were conducted to quantify street texture, an important factor affecting street particulate loads, street cleaning effectiveness and washoff of street surface particulates.

The sampling effort for the complete project is also summarized. This indicates the mass of information that was collected (and the field and laboratory work that was expended). The quality assurance program is described in detail. Again, the many special tests that were conducted to answer specific questions are completely documented. Also discussed are the more general sample container washing procedures and blank/replicate analyses.

CHAPTER II
SITE DESCRIPTION

STUDY AREA INVENTORY PROCEDURE

One of the first work elements of this project was to conduct inventories of the physiographic characteristics, land uses, and land management activities within the study areas. Climatic data for the area was also collected. The inventory involved several phases including: 1) general site characterization needed for program design; 2) delineation and refinement of the study areas utilizing large scale aerial photographs and field inspections; 3) characterization of the study area features relating to urban nonpoint sources of pollution; and 4) characterization of long-term and study year climatic conditions. Each of these phases is briefly described below.

General Site Characterization

At the start of the project, data were collected on each of the eight study sites. This inventory included mapping the stormwater sewerages, collecting general land use data and watershed characteristics, and rating the sites for factors affecting the stormwater pollutant loads. The study sites were initially identified on 1975 1"= 400' ratioed and rectified aerial photographs. This information, as well as information obtained by discussions with local public works officials, was then utilized in the design of various aspects of the study (such as identifying potential water quality sampling locations).

Detailing and Refinement of Study Areas

Once the study areas had been generally defined and the study design completed, each of the areas were redrawn on 1"= 100' ratioed and rectified aerial photographs taken in April, 1980. The boundaries of each study area were refined using available topographic and storm sewer maps and by field inspections. This refinement was especially important in the industrial and commercial areas, where large paved or rooftop areas were located near the area boundaries. The stormwater drainage flow patterns had to be determined by field inspections.

Characterization of the Study Areas

The principal site features relating to nonpoint pollution sources were identified. These included collection of data related to 1) urban lots, 2) streets and alleys, and 3) parking lots. The procedure used for evaluating residential structures (exterior housing) conditions had been initially developed for use in housing studies conducted by SEWRPC to assess relative housing conditions in the seven-county southeastern Wisconsin region. A copy of the data entry forms utilized for each element of the survey is included in Appendix A.

These inventories were conducted during the period from June to December 1980. An urban lot inventory was conducted for each land parcel. The land parcel consisted of either vacant land, a play lot, or a parcel of land associated with a residential, commercial, or industrial building. The urban land parcel inventory data included information on lawn, litter, pet waste, construction activity, and off-street parking conditions for each lot. As an example, such items were noted as percent slope, sod condition, areas of denuded soil, size of garden area, and presence of stock piles of material such as dirt and gravel for lawn areas.

For streets and alleys, data were collected on the type, condition, area covered, type and condition of curb and gutter, and type and condition of curb lawn (the grassed area between the curb and the sidewalk) and median area. Data were also collected concerning the traffic patterns and parking restrictions. The street and alley pavement lengths for street sweeping are discussed in terms of "curb miles", which is defined as the lineal distance of the curb, including the curb on both sides of the street or alley and both sides of medians. Data on parking lots were collected, including type and condition of surface, number of parking spots, utilization, and litter.

The exterior housing condition data served to expand and support the urban lot inventory data. The data obtained included the type, material, and exterior condition of foundations, walls, and roofs of buildings.

Climatic Summary

Long-term climatic data for the Southeastern Wisconsin Region were collected and reviewed. Study period precipitation information from weather observation stations situated closest to the study areas (West Allis and Mt. Mary College, Milwaukee) was recorded and compared with historical annual precipitation records. Rainfall intensity-duration-frequency relationships as well as historical information on the number and character of precipitation events were also summarized.

The following discussions present this site description and climatic data.

STUDY AREA DESCRIPTIONS

Four paired sets of study sites (each pair containing a control site and an experimental site) were selected for use in the Milwaukee NURP study. As shown in Table II.1, the sites ranged from 12.4 acres to 62.6 acres in size. Both sites in each pair ware close together to minimize differences in precipitation during the study. They were also matched with uniform land use types. Four of the sites drain to Lincoln Creek lying in the Milwaukee River watershed; two drain to Noyes Creek and one each drained to Honey Creek and the Menomonee River lying in the Menomonee River watershed. These two major watersheds both have a mix of urban and rural land uses. Urban land uses comprise about 58 percent of the land in the Menomonee River watershed and about 12 percent of the land area in the Milwaukee River watershed. The study area locations within these two watersheds are shown on Figure II.1-3.

At the time the study sites were selected, there were no known cross overs or connections between the existing sanitary sewers and the storm sewers.

The principal features and selected characteristics of each study area are discussed below. Pertinent information concerning each study site is presented on Tables II.1-7. Table II.7 shows the land cover breakdown (street

Table II.1

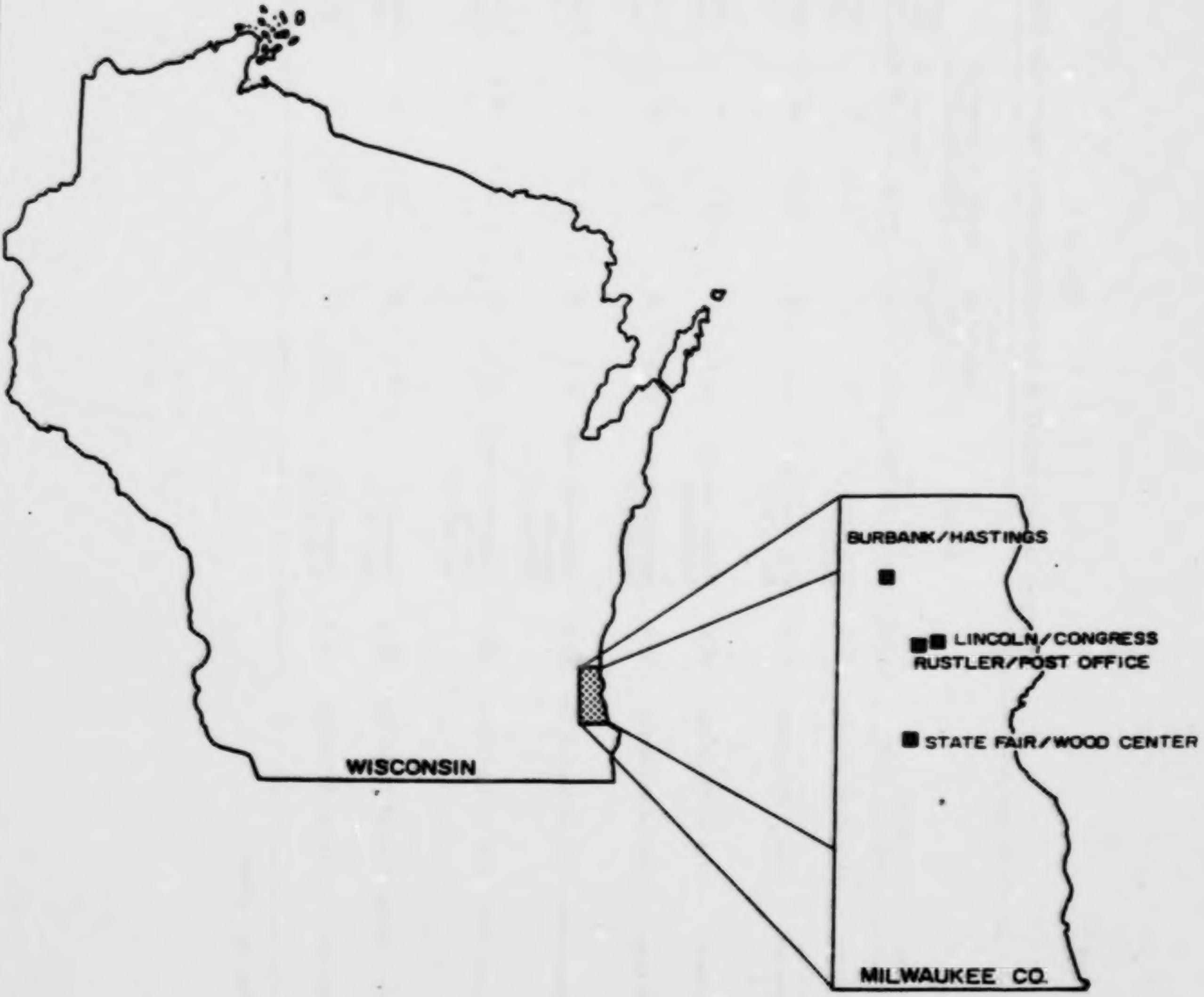
SELECTED CHARACTERISTICS OF THE PAIRED MILWAUKEE COUNTY NURP STUDY SITES: 1980

Study Site Name	Major Civil Division	Area (acres)	Primary Land Use Classification	Total Impervious Area		Directly Connected Impervious Area		Type of Storm Drainage System	Type of Sanitary Waste Disposal	Control or Experimental Sweeping Frequency	Receiving Stream
				Acres	Percent of Total Area	Acres	Percent of Total Area				
Lincoln	City of Milwaukee	36.1	High Density Residential	20.7	57	14.4	40	Subsurface Conduits	Sanitary sewer Service	Control	Lincoln Creek
Congress	City of Milwaukee	33.0	High Density Residential	16.6	50	11.3	34	Subsurface Conduits	Sanitary sewer service	Experimental	Lincoln Creek
Burbank	City of Milwaukee	62.6	Medium Density Residential	31.7	51	19.1	30	Subsurface Conduits	Sanitary sewer service	Control	Noyes Creek
Hastings	City of Milwaukee	32.8	Medium Density Residential	17.1	52	9.8	30	Subsurface Conduits	Sanitary sewer service	Experimental	Noyes Creek
Wood Center	City of West Allis	44.9	Commercial/High Density Residential	36.4	81	32.6	72	Subsurface Conduits	Sanitary sewer service	Control	Menomonee River
State Fair	City of West Allis	29.0	Commercial/High Density Residential	22.4	77	20.2	70	Subsurface Conduits	Sanitary sewer service	Experimental	Honey Creek
Post Office	City of Milwaukee	12.4	Commercial Parking Lot	12.1	98	12.1	98	Subsurface Conduits	Sanitary sewer service	Control	Lincoln Creek
Rustler	City of Milwaukee	12.4	Commercial/ Parking Lot	12.4	100	12.4	100	Subsurface Conduits	Sanitary sewer service	Experimental	Lincoln Creek

Source: SEWRPC

Figure II.1

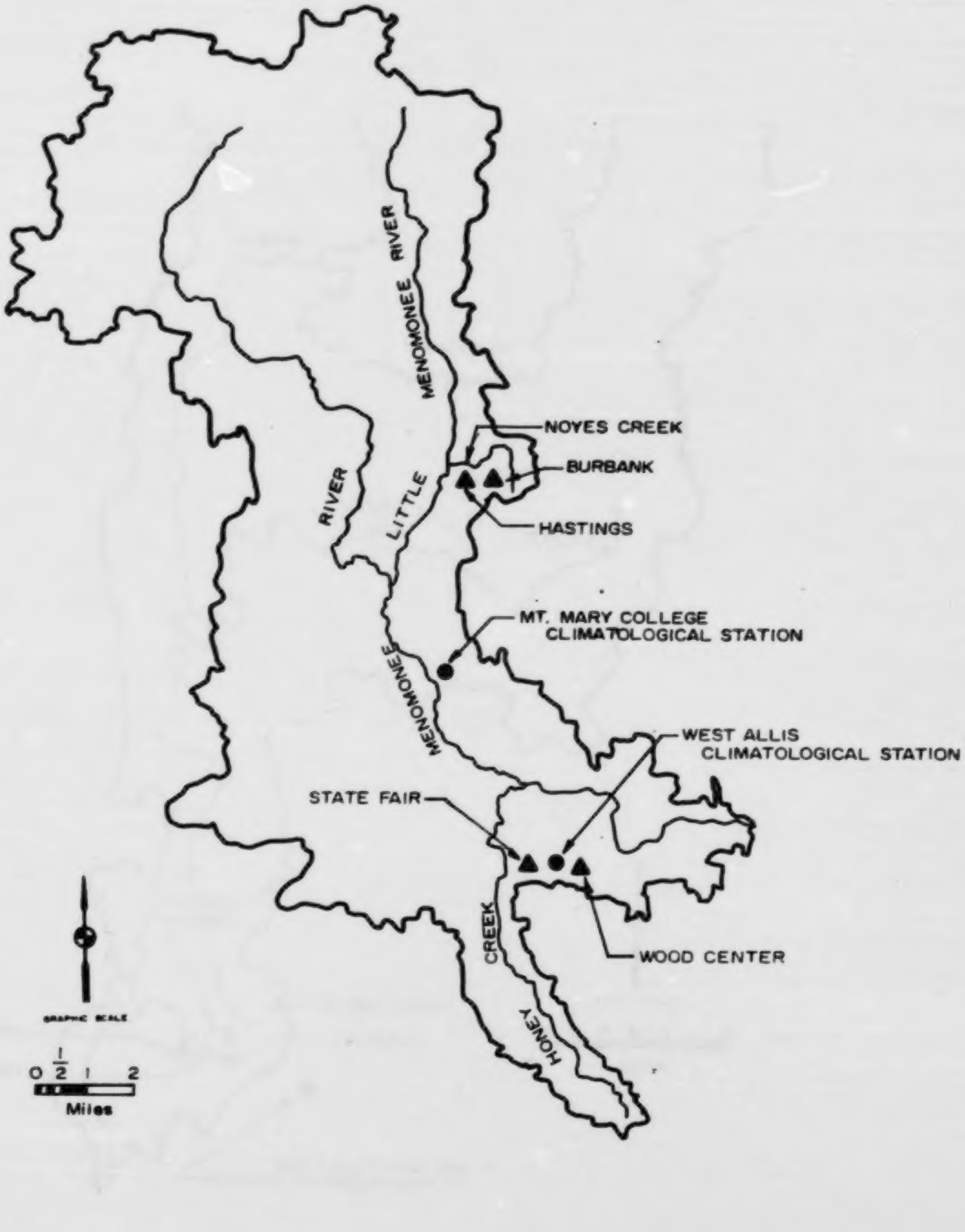
THE LOCATION OF PAIRED NURP STUDY SITES IN MILWAUKEE COUNTY, WISCONSIN


BURBANK/HASTINGS
LINCOLN/CONGRESS
RUSTLER/POST OFFICE
STATE FAIR/WOOD CENTER
WISCONSIN
MILWAUKEE CO.

Source: SEWRPC.

Figure II.2

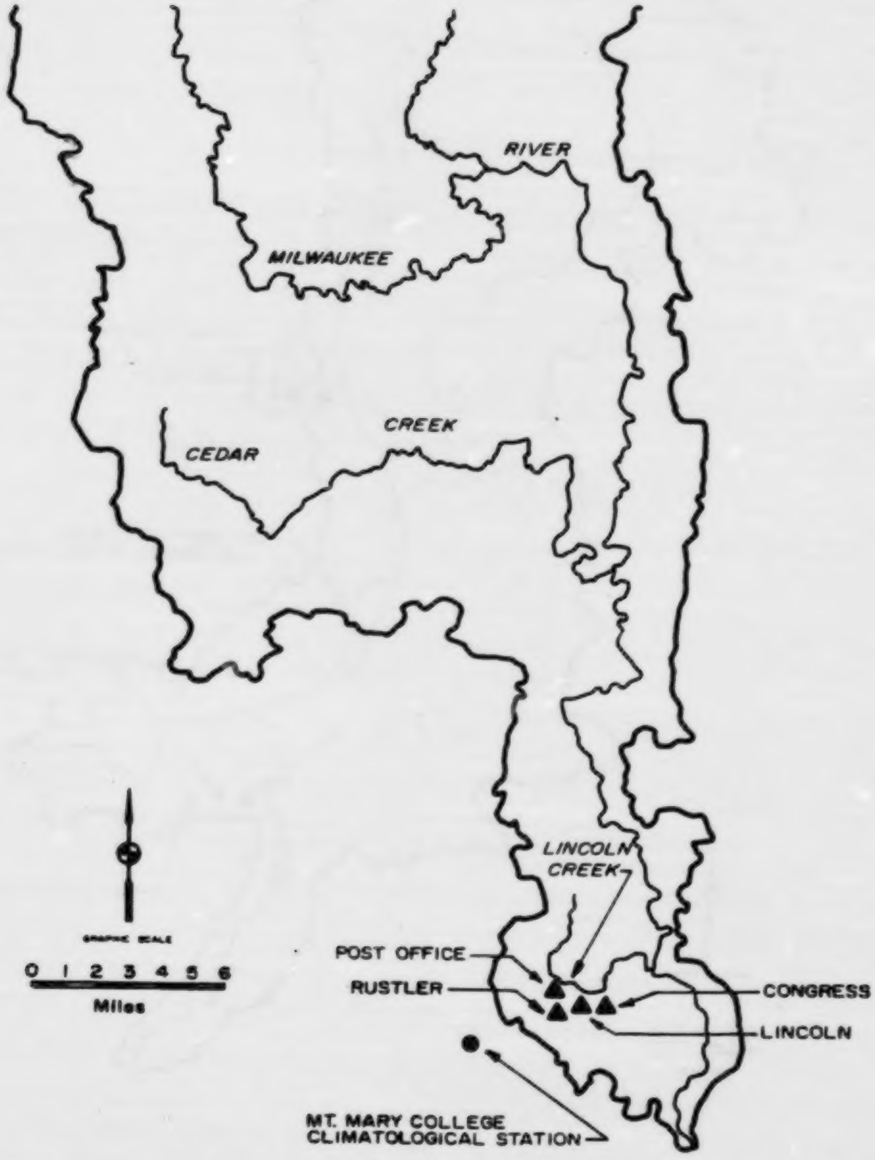
THE LOCATION OF MILWAUKEE COUNTY NURP STUDY SITES, CLIMATOLOGICAL OBSERVATION STATIONS, AND MAJOR STREAMS IN THE MENOMONEE RIVER WATERSHED


MENOMONEE RIVER
LITTLE
RIVER
NOYES CREEK
BURBANK
HASTINGS
MT. MARY COLLEGE
CLIMATOLOGICAL STATION
MENOMONEE
WEST ALLIS
CLIMATOLOGICAL STATION
STATE FAIR
WOOD CENTER
CREEK
HONEY
GRAPHIC SCALE
0 1/2 1 2
Miles

Source: SEWRPC

Figure II.3

THE LOCATION OF MILWAUKEE COUNTY NURP STUDY SITES AND MAJOR STREAMS IN THE MILWAUKEE RIVER WATERSHED


RIVER
MILWAUKEE
CREEK
CEDAR
LINCOLN CREEK
GRAPHIC SCALE
0 1 2 3 4 5 6
Miles
POST OFFICE
RUSTLER
CONGRESS
LINCOLN
MT. MARY COLLEGE CLIMATOLOGICAL STATION

Source: SEWRPC.

Table II.2

LENGTH AND AREA OF STREETS AND ALLEYS ASSOCIATED WITH VARIOUS LAND USES WITHIN THE PAIRED MILWAUKEE COUNTY NURP STUDY SITES: 1980

Study Site	Study Site Area (acres)	Length[a] and Area[b] of Street Pavement Associated with Various Land Uses (curb miles including alleys)											
		Single- or Two-Family Residential		Townhouse and Garden Apartments		Commercial Areas		Industrial Areas		Central Business District		Total	
		(length)	(area)	(length)	(area)	(length)	(area)	(length)	(area)	(length)	(area)	(length)	(area)
Lincoln.....	36.1	4.4	6.8	0.0	0.0	0.1	0.6	0.0	0.0	0.0	0.0	4.5	7.4
Congress....	33.0	3.5	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	5.6
Burbank.....	62.6	4.1	9.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1	9.4
Hastings....	32.8	2.2	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	4.3
Wood Center.	44.9	1.5	4.5	0.3	0.0	2.7	5.8	0.7	1.9	0.0	0.0	5.2	12.2
State Fair..	29.0	1.3	2.3	0.0	0.0	0.0	0.0	0.0	0.0	2.2	4.8	3.5	7.1
Post Office.	12.4	0.0	0.0	0.0	0.0	0.7	1.4	0.0	0.0	0.0	0.0	0.7	1.4
Rustler.....	12.4	0.0	0.0	0.0	0.0	0.6	1.2	0.0	0.0	0.0	0.0	0.6	1.2

[a] The street pavement length reported in terms of curb miles includes the lineal distance of the curb including both sides of the street pavement and both sides of medians and also includes the lineal distance of both sides of the alleys between the adjoining street curbs.

[b] Surface area of the paved portions of the streets and alleys is reported in acres.

Source: SEWRPC

Table II.3

STREET SURFACE CHARACTERISTICS AND VEHICLE PARKING RESTRICTIONS WITHIN THE PAIRED MILWAUKEE COUNTY NURP STUDY SITES: 1980

	Streets and Alleys Surface Type and Condition (curb miles[a,b])					Vehicle Parking Restrictions on Streets (excluding alleys)	
	Concrete		Asphalt				
Study Site	Good	Poor	Good	Poor	Total	Restricted Curb Miles[a]	Unrestricted Curb Miles[a]
Lincoln	2.8	1.6	0.0	0.1	4.5	0.1	2.6
Congress	1.9	1.6	0.0	0.0	3.5	0.0	2.4
Burbank	4.0	0.1	0.0	0.0	4.1	0.0	4.1
Hastings	2.2	0.0	0.0	0.0	2.2	0.0	2.2
Wood Center	0.8	0.2	0.6	3.6	5.2	2.7	1.4
State Fair	0.5	0.1	0.9	2.0	3.5	2.2	0.1
Post Office	0.0	0.0	0.4	0.3	0.7	0.7	0.0
Rustler	0.0	0.0	0.6	0.0	0.6	0.6	0.0

[a] The street pavement length reported in terms of curb miles includes the lineal distance of the curb including both sides of the street pavement and both sides of medians and also includes the lineal distance of both sides of the alleys between the adjoining street curbs.

[b] Roadway surface conditions were rated using a modification of a methodology developed by the Illinois Department of Transportation for use in highway project programming. Values were assigned according to a scale ranging in decending order from 9.0 to 1.0. Surfaces rated from 6.1 to 9.0 were considered good, pavements and surfaces rated from 6.0 to 1.0 were considered poor. Generally, surfaces receiving good ratings exhibited a relatively smooth surface and was free of major cracks, missing pavement, and major patching. Surfaces receiving poor ratings generally exhibited wider and more numerous cracks, some areas of missing pavement, and in the case of asphalt surfaces, some degree of rutting. The methods utilized to categorize street surfaces are described in more detail in SEWRPC Study Memorandum NURP A.1.

Source: SEWRPC.

H0103-E(2)

Table II.4

SELECTED CHARACTERISTICS OF OFFSTREET PARKING AREAS WITHIN THE PAIRED MILWAUKEE COUNTY NURP SITES: 1980

Study Site	Area of Parking Lots Associated with Various Land Uses (square feet)					Parking Lot Surface Type and Condition[a] (square feet)					
	Single- or Two-Family Residential	Townhouse and Garden Apartments	Commercial Areas	Industrial Areas	Central Business District	Concrete		Asphalt		Gravel	Total
						Good	Poor	Good	Poor		
Lincoln........	0	0	9,800	0	0	0	0	0	9,800	0	9,800
Congress.......	25,900	4,790	0	0	0	4,790	0	25,900	0	0	30,690
Burbank........	0	0	0	0	0	0	0	0	0	0	0
Hastings.......	0	0	0	0	0	0	0	0	0	0	0
Wood Center....	0	17,110	271,770	36,600	0	11,300	19,470	191,210	71,700	31,800	325,480
State Fair.....	0	0	0	0	206,780	6,670	23,400	90,410	80,600	5,700	206,780
Post Office....	0	0	465,060	0	0	0	0	161,890	303,170	0	465,060
Rustler........	0	0	262,070	0	0	0	0	131,320	130,750	0	262,070

---

[a] Parking lot surface conditions were rated using a modification of a methodology developed by the Illinois Department of Transportation for use in highway project programming. Values were assigned according to a scale ranging in decending order from 9.0 to 1.0. Surfaces rated from 6.1 to 9.0 were considered good, pavements and surfaces rated from 6.0 to 1.0 were considered poor. Generally, surfaces receiving good ratings exhibited a relatively smooth surface and were free of major cracks, missing pavement, and major patching. Surfaces receiving poor ratings generally exhibited wider and more numerous cracks, some areas of missing pavement, and in the case of asphalt surfaces, some degree of rutting. The methods utilized to categorize parking lot surfaces are described in more detail in SEWRPC Study Memorandum NURP A.1.

Source: SEWRPC.

Table II.5

SELECTED LAND PARCEL CHARACTERISTICS IN THE LINCOLN, CONGRESS, BURBANK, HASTINGS, WOOD CENTER, AND STATE FAIR MILWAUKEE COUNTY NURP STUDY SITES[a]: 1980

Study Site	Number of Parcels	Lawn Surface Conditions				Average Eroded Area per Parcel (ft^2)	Litter				Number of Parcels with Pet Waste Observed	Number of Parcels with Construction Activity Observed
		Percentage of Parcels[b]					Percentage of Parcels with Litter Observed					
		Excellent	Good	Fair	Poor		None	Low	Mod.	High		
Lincoln.....	244	24	67	8	1	60	66	32	2	--	7	5
Congress....	208	12	78	10	0	75	56	38	5	1	6	1
Burbank.....	306	18	73	5	4	44	78	20	2	--	21	12
Hastings....	188	22	75	3	0	52	82	18	--	--	6	7
Wood Center.	228	8	52	11	4	49	13	61	17	9	14	2
State Fair..	156	4	51	10	1	45	9	62	23	6	6	1

[a] This table does not include the two study sites which are entirely composed of parking lots.

[b] Percentage of parcels with various lawn surface conditions at the Wood Center and State Fair sites do not total 100 percent due to a number of commercial parcels with no lawn surface.

Source: SEWRPC

TRB/ib
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H0104B-V

Table II.6

CLASSIFICATION OF BUILDINGS LOCATED WITHIN THE LINCOLN, CONGRESS, BURBANK, HASTINGS, WOOD CENTER, AND STATE FAIR MILWAUKEE COUNTY NURP SITES[a]: 1980

		Structure Use Classification			
Study Site	Number of Structures	Percent Single-Family	Percent Two-Family	Percent Multi-Family	Percent Mixed Use
Lincoln	244	94	5	0.5	0.5
Congress	207	90	7	1.5	1.5
Burbank	305	100	--	--	--
Hastings	188	100	--	--	--
Wood Center ..	228	45	22	1	32
State Fair ...	156	40	18	3	39

[a] This table does not include the two study sites which are entirely composed of parking lots.

Source: SEWRPC

H01048-S

Table II.7

LAND COVER WITHIN THE PAIRED MILWAUKEE COUNTY NURP SITES: 1980

Land Cover Categories	Lincoln		Congress		Burbank		Hastings		Wood Center		State Fair		Post Office		Rustler	
	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent
Streets	5.4	15.0	3.4	10.3	9.4	15.0	4.3	13.1	11.3	25.2	5.8	20.0	1.4	11.3	1.2	9.7
Alleys	2.0	5.5	1.8	5.8	0.0	0.0	0.0	0.0	0.9	2.0	1.3	4.5	0.0	0.0	0.0	0.0
Offstreet Parking	0.2	0.5	0.7	0.7	0.0	0.0	0.0	0.0	7.5	16.7	4.7	16.2	10.7	86.3	6.0	48.4
Directly Connected Walks and Driveways	5.4	15.0	4.1	12.4	6.9	11.0	3.8	11.6	5.4	12.0	2.5	8.6	0.0	0.0	0.0	0.0
Directly Connected Rooftops	1.4	3.9	1.3	3.9	2.8	4.5	1.7	5.2	7.5	16.7	5.9	20.3	0.1	0.1	5.2	41.9
Non-Connected Rooftops	5.0	13.9	3.6	10.9	8.5	13.6	4.8	14.6	3.1	6.9	1.9	6.6	0.0	0.0	0.0	0.0
Other Impervious Areas	1.3	3.6	1.7	5.2	4.1	6.5	2.5	7.6	0.7	1.6	0.3	1.0	0.0	0.0	0.0	0.0
Total Directly Connected Impervious Area	14.4	40.0	11.3	34.2	19.1	30.5	9.8	29.9	32.6	72.6	20.2	69.6	12.1	97.6	12.4	100.0
Total Impervious Area	20.7	57.4	16.6	50.3	31.7	50.6	17.1	52.1	36.4	81.1	22.4	77.2	12.1	97.6	12.4	100.0
Total Pervious Area	15.4	42.6	16.4	49.7	30.9	49.4	15.7	47.9	8.5	18.9	6.6	22.8	0.3	2.4	< 0.1	< 0.1
Total Study Area	36.1	100.0	33.0	100.0	62.6	100.0	32.8	100.0	44.9	100.0	29.0	100.0	12.4	100.0	12.4	100.0

Source: SEWRPC

surfaces, parking lots, landscaped areas, vacant lots, etc.) for each of the Milwaukee County NURP study sites. The STORET numbers for the eight Milwaukee county NURP sampling sites are as follows:

Wood Center	#413631
State Fair	#413630
Post Office	#413635
Lincoln	#413636
Congress	#413637
Burbank	#413633
Hastings	#413632
Rustler	#413634

Lincoln Study Site

The Lincoln study site was paired with the Congress study site and is a high density residential area. It was the street cleaning control area for this site pair. The Lincoln study site has a drainage area of 36.1 acres and is located in Section 2, Township 7 North, Range 21 East, in the City of Milwaukee. The runoff sampling station was located at the intersection of W. Lincoln Creek Parkway and N. 54th Street, immediately upstream from the outfall into Lincoln Creek. The site is shown on Figure II.4.

About 4.5 curb miles of streets and alleys are in this study area, with 4.4 curb miles in residential areas and 0.1 curb miles in commercial areas. The traffic volume on the portion of W. Congress Street which passes through this study area was estimated to be about 3,900 vehicles per average weekday. The traffic volume on the residential streets was estimated to be about 200 vehicles per average weekday. The paved residential streets and alleys in this area cover about 6.8 acres and about 0.6 acre of paved streets and alleys are in commercial areas. About 244 developed land parcels are in this site. Almost all (about 94 percent) have single family dwellings, with some two family dwellings, multiple family dwellings, and mixed uses. Nearly all of the houses are of wood frame construction, with a small number constructed of structural masonry.

About 20.7 acres (57 percent) of this site is impervious and 15.4 acres (43 percent) is pervious. Most of the impervious area (15.7 acres or 43 percent) is directly connected. About 0.3 acres (2 percent) of the pervious area was not covered with vegetation. This averages about 60 square feet per parcel. Pet waste was found on about three percent of the parcels at this site.

Congress Study Site

The Congress study site was paired with the Lincoln study site and is also a high density residential area. It was the street cleaning experimental site for these paired areas. The Congress study site has a drainage area of 33.0 acres and was located in Section 2, Township 7 North, Range 21 East, in the City of Milwaukee. The runoff sampling station is located at the intersection of W. Congress and N. 48th Street, immediately upstream from the outfall into Lincoln Creek. The site is shown on Map Figure II.5.

All of the 3.5 curb miles of streets and alleys in the site are located in residential areas. The traffic volume on W. Congress Street was about 3,800 vehicles per average weekday. Traffic volumes on the residential streets were estimated to average about 240 vehicles per average weekday. The paved portion of the streets in this study area cover about 3.4 acres. About 208 developed land parcels are in this area. Almost all (90 percent) of the lots have single family dwellings with some lots having two family dwellings, multiple family dwellings, and mixed uses. Nearly all of the buildings in this site are of wood frame construction, with a small number constructed of structural masonry.

Approximately 16.6 acres (50 percent) of this site is impervious and 16.4 acres (50 percent) is pervious. Much of the impervious area (11.3 acres, or 34 percent) is directly connected. About half of the residential lots are steeply sloped for the first few feet back from the sidewalk. About 0.4 acres (2 percent) of the pervious area was not covered with vegetation. This averages about 75 square feet per parcel. Pet waste was found on about three percent of the parcels in this study site.

Burbank Study Site

The Burbank study site was paired with the Hastings study site and is a medium density residential area. It was the street cleaning control area for these paired areas. The Burbank study site has a drainage area of about 62.6 acres and is the largest of the study sites. It is located in part of Section 21, Township 8 North, Range 21 East, in the City of Milwaukee. The runoff sampling station was located on N. Burbank Street at its intersection with Noyes Park Creek. The site is shown on Figure II.6.

All of the 4.1 curb miles of streets are located in residential areas. Traffic volumes on each of the streets were estimated to be about 275 vehicles per average weekday. The paved portion of the streets in this study area cover about 9.4 acres. There are no alleys in the N. Burbank Street study site. A total of 306 developed land parcels are in this study area. All of these parcels are occupied by single family dwellings, with the exception of one parcel which is a Milwaukee County park system playlot. Nearly all of the houses in the site are of wood frame construction, with a few constructed of structural masonry.

About 31.7 acres (51 percent) of this area is impervious, and 30.9 acres (or 49 percent) is pervious. Much of the impervious area (19.1 acres, or 30 percent) is directly connected. About 0.3 acre (1 percent) of the pervious area was not covered with vegetation. This averages 44 square feet per parcel. Pet waste was found on about seven percent of the parcels. Construction activity (to replace 600 feet of sanitary sewer) occurred along N. 84th Street during the fall of 1980.

Hastings Study Site

The Hastings study site was paired with the Burbank study site and is also a medium density residential area. It was the street cleaning experimental area for these paired areas. This site has a drainage area of about 32.8 acres. It is located in Section 21, Township 8 North, Range 21 East, in the City of Milwaukee. The runoff sampling station was located on N. Hastings Street at its intersection with Noyes Park Creek. The site is shown on Figure II.7.

All of the 2.2 curb miles of streets are located in residential areas. Traffic volumes were estimated to be 150 vehicles per average weekday. The paved portions of the streets in this area cover about 4.3 acres. There are no alleys in the N. Hastings Street study site. A total of 188 developed land parcels were in this site. All of the parcels have single family dwellings. Nearly all of the houses in this site are of wood frame construction, with a few constructed of structural masonry.

About 17.1 acres (52 percent) of this area is impervious, and 15.7 acres (48 percent) is pervious. Much of the impervious area (9.8 acres, or 30 percent) is directly connected. About 0.2 acre (1 percent) of the pervious area was not covered with vegetation. This averages about 52 square feet per parcel. Pet waste was found on about three percent of the parcels.

Wood Center Study Site

The Wood Center study site was paired with the State Fair study site and is a commercial/high density residential area. It was the street cleaning control area for these paired areas. The Wood Center study site has a drainage area of 44.9 acres and is located in parts of Sections 34 and 35, Township 7 North, Range 21 East, and Sections 2 and 3, Township 6 North, Range 21 East, in the City of West Allis. The runoff sampling station was located on the Wood Center Veterans Administration property just north of Greenfield Avenue on the east end of the study site. The area, which drains to the Menomonee River, is shown on Figure II.8.

About 5.2 curb miles of streets and alleys are in the site, with 1.5 curb miles in residential areas, 0.3 curb mile in areas with townhouse-garden apartments, 2.7 curb miles in commercial areas, and 0.7 curb mile in industrial areas. The traffic volume on W. Greenfield Ave. was about 12,200 vehicles per average weekday. The traffic volume on West National Avenue was estimated to range from 8,800 vehicles per average weekday in the western portion of the study site to 11,400 vehicles per average weekday in the eastern portion. The paved portions of the streets and alleys in this study area cover about 4.5 acres in residential areas, 5.8 acres in commercial areas, and 1.9 acres in industrial areas. A total of 228 developed land parcels are in this site. Of this total, 32 percent (or 73 parcels) are classified as commercial or mixed commercial and residential, with the remaining 68 percent occupied by single, two, or multi-family residences. The most common buildings in this site are two-story wood frame structures. About 30 percent of the buildings are single story, 60-percent have two stories, and 10 percent have three stories. About 88 percent of the buildings are of wood frame construction, five percent are of metal construction, six percent are of concrete construction, and one percent are constructed of structural masonry.

About 36.4 acres (81 percent) of this area is impervious and 8.5 acres (19 percent) is pervious. Most of the impervious area (32.6 acres, or 73 percent) is directly connected. About 0.2 acre (2.3 percent) of the pervious area was not covered with vegetation. This averages about 49 square feet per parcel. Pet waste was found on about five percent of the parcels.

State Fair Study Site

The State Fair study site was paired with the Wood Center study site and is a commercial/high density residential area. It was the street cleaning experimental area for these paired sites. The State Fair study site has a drainage area of 29.0 acres and is located in Sections 33 and 34 in Township 7 North, Range 21 East, and Sections 3 and 4, Township 6 North, Range 21 East; all in the City of West Allis. A runoff sampling station was located near the intersection of S. 77th Street and W. Madison Avenue on the property of the Wisconsin State Fairgrounds. This study area, which drains to Honey Creek, is shown on Figure II.9.

About 3.5 curb miles of streets and alleys are in this site, with about 2.2 curb miles in the Central Business District and 1.3 miles in residential areas. Traffic volumes on W. Greenfield Avenue was about 15,200 vehicles per average weekday. The paved portions of the streets and alleys adjacent to the residential areas and Central Business District portions of this study site covered about 2.3 and 4.8 acres, respectively. A total of 156 developed land parcels are in this site. Of this total, 39 percent (61 parcels) are classified as commercial or a combination of commercial and residential. The remaining parcels are residential. About 33 percent of the buildings in this site are one-story buildings, while 64 percent are two-story buildings and three percent are three-story buildings. One building in the site is a six-story hotel. About 67 percent of the buildings are of wood frame construction, 22 percent are of metal construction, 15 percent are of cement construction, and one percent are constructed of structural masonry.

About 22.4 acres (77 percent) of this area is impervious and 6.6 acres (23 percent) is pervious. Most of the impervious area (20.2 acres, or 70 percent) is directly connected. Most of the commercial parcels do not have lawns. Grassed areas, if any, tend to be located in the street right-of-way. Each parcel in this study site had an average of 45 square feet of bare ground. Pet litter was found on about four percent of the parcels.

Post Office Study Site

The Post Office study site was paired with the Rustler study site and is a commercial/parking lot area. It was the street cleaning control area for these paired areas. The Post Office study site is 12.4 acres in size and is shown on Figure II.10. The study site is part of a large shopping center and is located in Section 2, Township 7 North, Range 21 East, in the City of Milwaukee. The area drains to Lincoln Creek. Approximately 12.1 acres (98 percent) of the study site is impervious. The parking lot area (10.6 acres) was sub-divided into five subareas, as shown on Figure II.10. The runoff sampling site was located in Area 3. Characteristics of the parking lot areas are shown on Table II.8.

Parking Area One is 1.6 acres in size with space to park 142 vehicles. It is located in a corner of the site far from the shopping area. This parking area appears to be used infrequently. Area Two is 2.1 acres in size with space for 240 vehicles. This subarea also appears to receive little use. Area Three is 1.1 acres in size with space to park 162 vehicles. This sub-

Table II.8

SELECTED CHARACTERISTICS OF THE PARKING AREA FOR THE POST OFFICE AND RUSTLER STUDY SITES: 1980

Area	Litter				Area of Parking Lot (Acres)	Spaces Available for Cars	Description of Site
	None	Low	Mod.	High			
Post Office #1.......	--	X	--	--	1.6	142	Asphalt parking lot.
Post Office #2.......	--	--	--	X	2.1	240	Asphalt parking lot, a present.
Post Office #3.......	--	--	--	X	1.1	162	Asphalt parking lot, Post Office sub-station present.
Post Office #4.......	--	--	X	--	4.2	574	Asphalt parking lot.
Post Office #5.......	--	X	--	--	1.6	204	Asphalt parking lot.
Rustler #1...	--	--	X	--	3.0	351	Asphalt parking lot.
Rustler #2...	--	--	--	X	0.1	12	Building occupies the majority of this area.
Rustler #3...	--	--	X	--	3.0	393	Asphalt parking lot.

Source: SEWRPC.

area appears to get little use. A U.S. Postal Service sub-station is located in this area. Area Four is 4.2 acres in size and contains spaces for 574 vehicles. This area is located adjacent to the building and is quite heavily used. Area Five is 1.6 acres in size with spaces to park 205 vehicles. This area is also near the building, but is not frequently used.

Rustler Study Site

The Rustler study site was paired with the Post Office study site and is also a commercial/parking lot area. It was the street cleaning experimental area for these paired sites. The Rustler study site is approximately 12.4 acres in size and is shown on Figure II.10. The site is part of a large shopping center which is located in Section 2, Township 7 North, Range 21 East, in the City of Milwaukee. The runoff sampling station was located in Area Three of this site. The site drains to Lincoln Creek. All of this study area is impervious rooftop or parking lot. The parking lot area (6.1 acres) was sub-divided into three subareas, as shown on Figure II.10, which are described on Table II.8. The site includes a large portion of the shopping area building itself.

Parking Area One is 3.0 acres in size, with parking spaces available for 351 vehicles. This parking area is moderately used. Area Two is 0.1 acre in size with spaces for 12 vehicles. This area is heavily used. There is no grass at this site, and stormwater from the roof is piped directly to a storm sewer. Area Three is about 3.0 acres in size, with space available for 393 vehicles. This parking area is moderately used.

CLIMATIC SUMMARY

Introduction

Southeastern Wisconsin (including Milwaukee) has a continental climate with four seasons, each having varying durations and unsteady transitions. Summers (usually June, July, and August) are relatively warm with occasional periods of hot, humid weather and sporadic periods of very cool weather. Winters, usually December, January, and February, may in some years be lengthened to include all or parts of November and March. Winters tend to be cold, cloudy, and snowy. There is often a short midwinter thaw caused by brief periods of unseasonably warm weather.

Autumn and spring in southeastern Wisconsin are transition periods between the dominant winter and summer seasons. They are usually periods of unsettled weather conditions. Temperatures are extremely varied and long periods of precipitation are common. Early spring is marked by raising temperatures. By late March, rainfall replaces snow as the predominant form of precipitation. Typical spring weather may extend from March through May and is characterized by cool, wet weather. Typical autumn weather may extend from September through November, and is characterized by pleasant, mild, sunny days and cool nights.

Long-Term Climatic Data in Southeastern Wisconsin

Air temperatures in southeastern Wisconsin are subject to great seasonal changes and yearly and diurnal variations. Air temperatures may control many

Figure II.4

LINCOLN STUDY SITE

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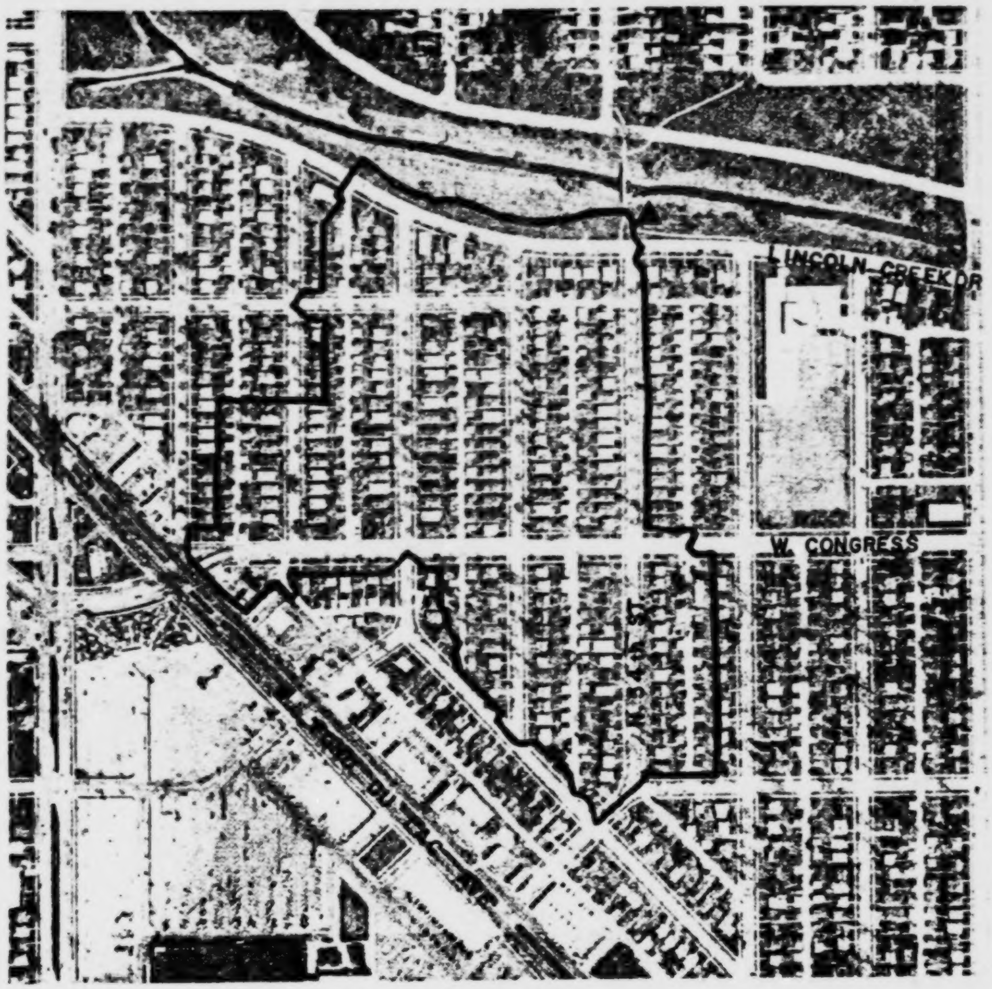
LINCOLN CREEK DR
W. CONGRESS
N. 54 ST

LEGEND
—— STUDY SITE BOUNDARY
▲ SAMPLING STATION

SCALE–1" = 500'

Source: SEWRPC.

Figure II.5

CONGRESS STUDY SITE

Reproduced from
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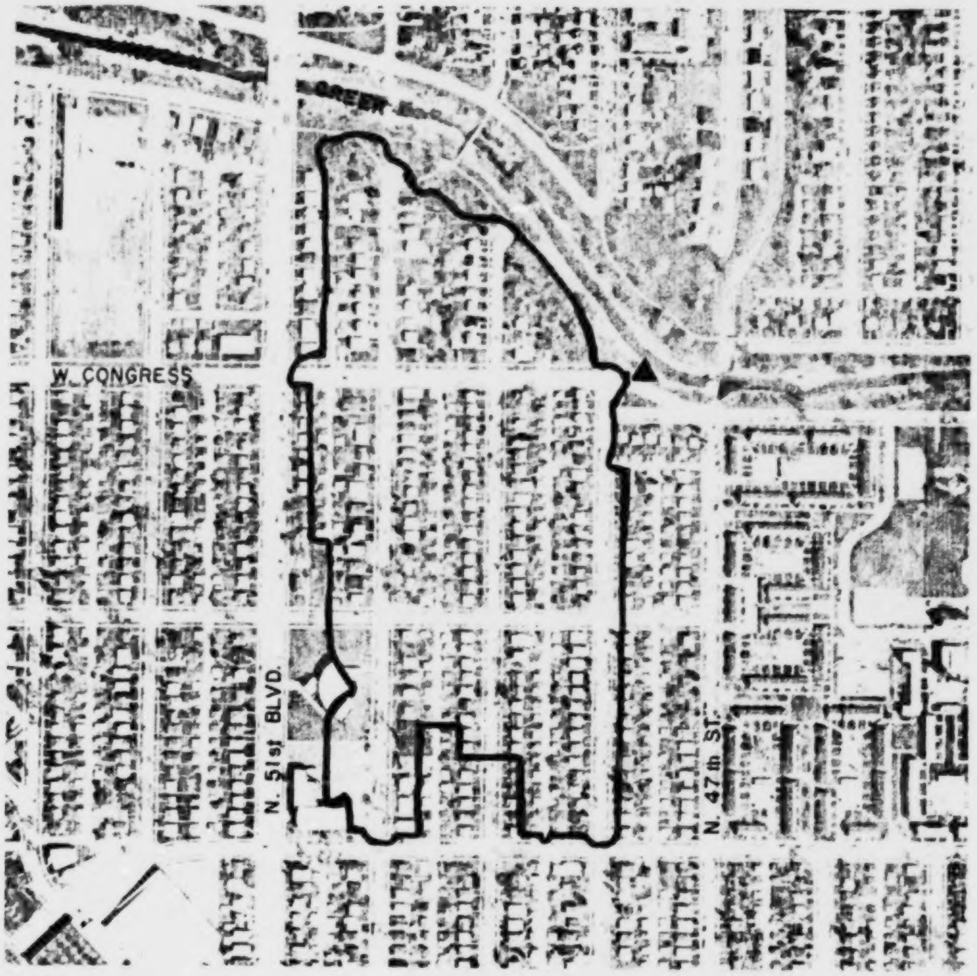
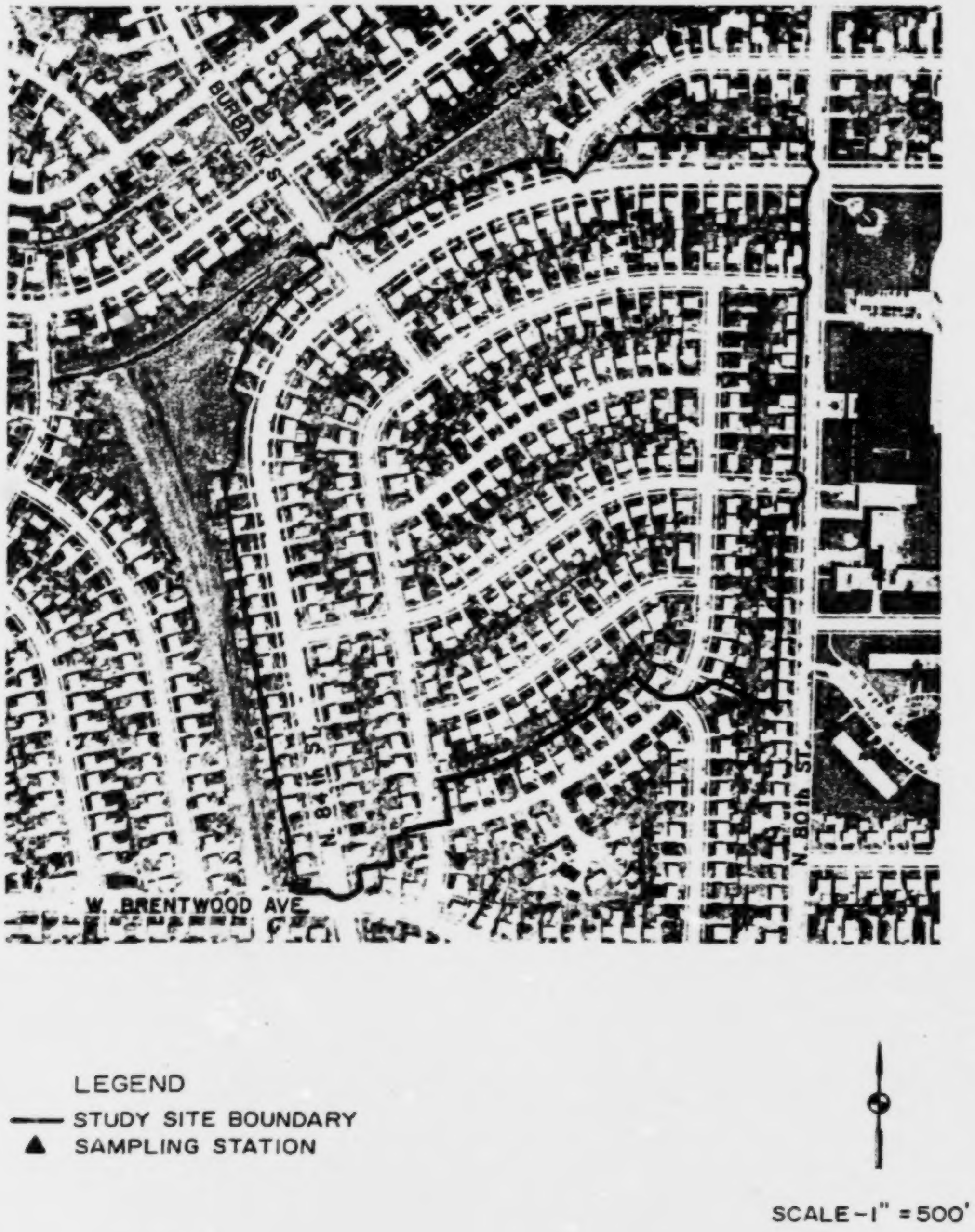

GREEN
W. CONGRESS
N. 51st BLVD.
N. 47th ST.

LEGEND
— STUDY SITE BOUNDARY
▲ SAMPLING STATION

SCALE-1" = 500'

Source: SEWRPC.

Figure II.6
BURBANK STUDY SITE


N. BURBANK ST.
N. 84th ST.
N. 80th ST.
W. BRENTWOOD AVE.
LEGEND
STUDY SITE BOUNDARY
▲ SAMPLING STATION
SCALE-1" =500'

Source: SEWRPC.

Figure II.7

HASTINGS STUDY SITE

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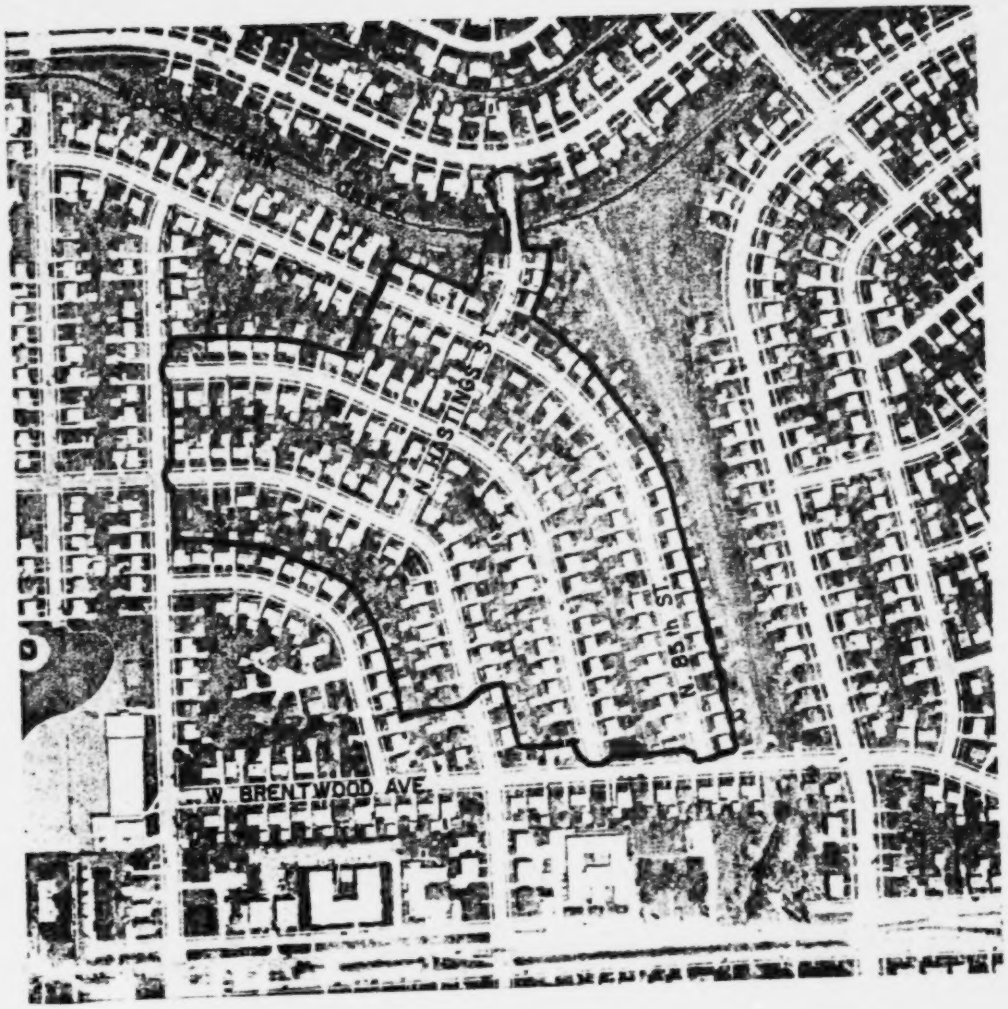

N. HASTINGS ST.
N. 85th ST.
W. BRENTWOOD AVE.

LEGEND

— STUDY SITE BOUNDARY

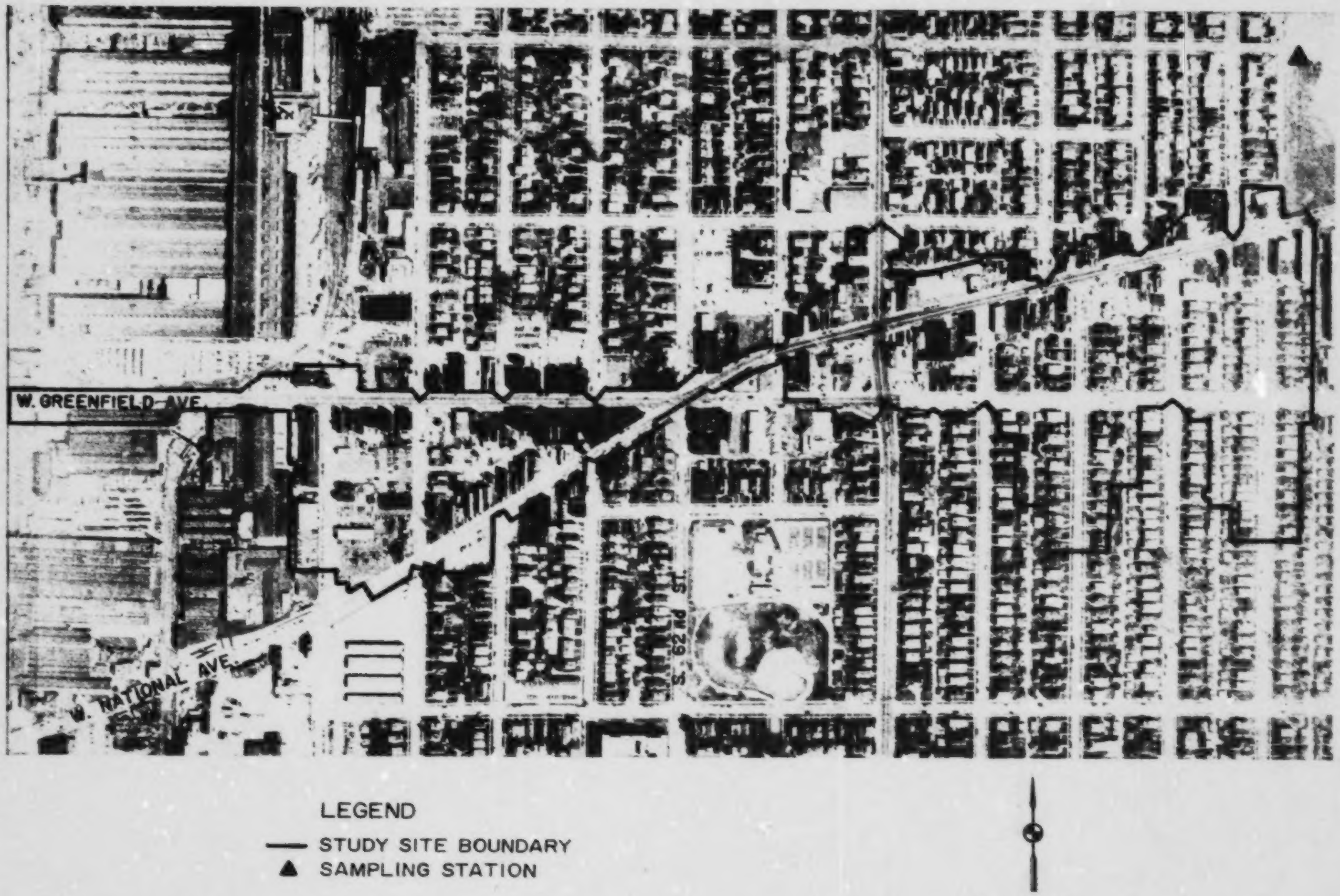
▲ SAMPLING STATION

SCALE-1" =500'

Source: SEWRPC.

Figure II.8

WOOD CENTER STUDY SITE

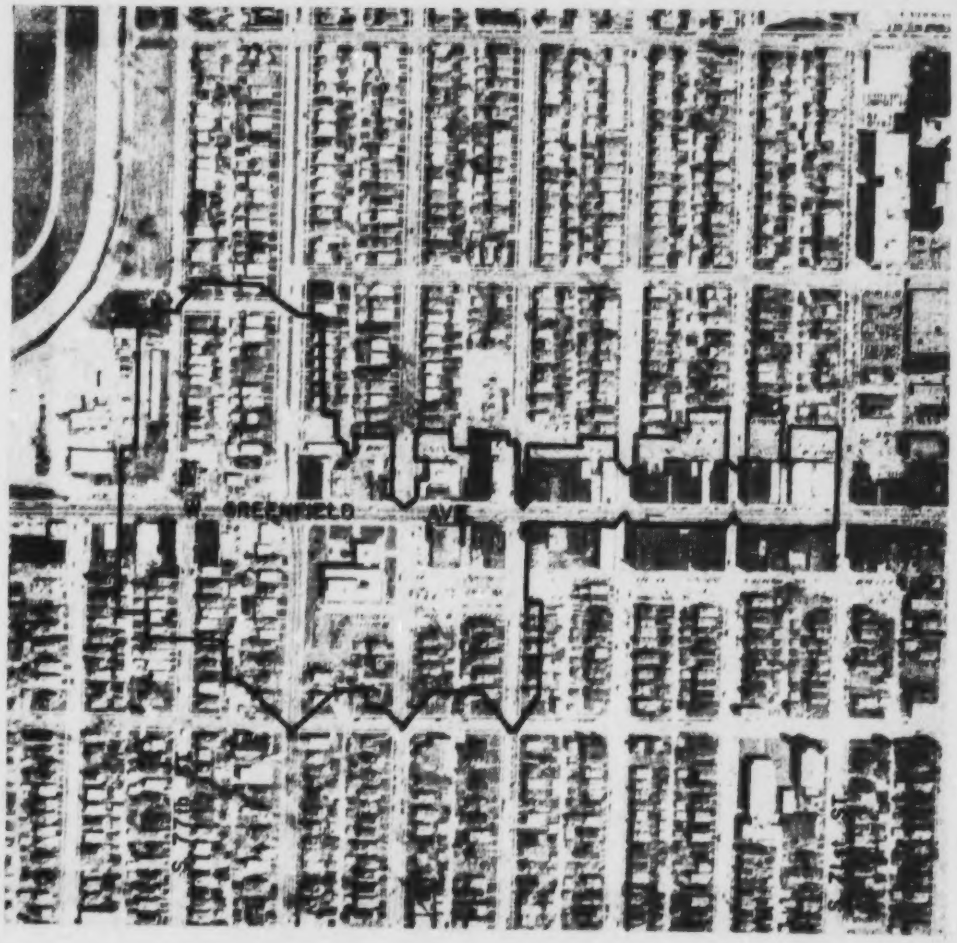

W. GREENFIELD AVE.
W. NATIONAL AVE.
S. 62nd ST.
LEGEND
STUDY SITE BOUNDARY
▲ SAMPLING STATION

SCALE—1" = 500'

Source: SEWRPC.

Figure II.9
STATE FAIR STUDY SITE

Reproduced from
best available copy.


W. GREENFIELD AVE.
S. 77th
ST

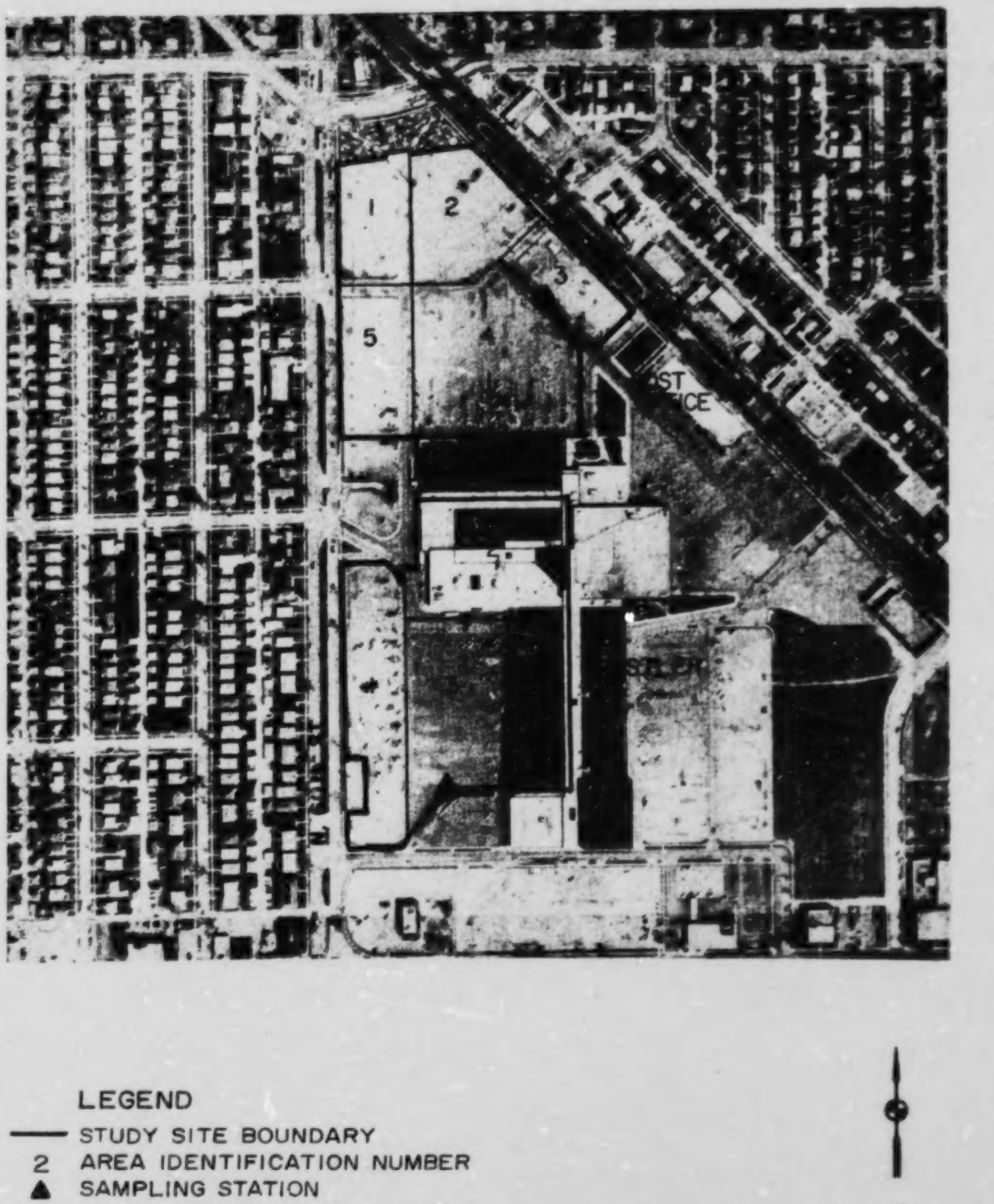
LEGEND
— STUDY SITE BOUNDARY
▲ SAMPLING STATION

SCALE – 1" = 500'

Source: SEWRPC.

Figure II.10

POST OFFICE AND RUSTLER STUDY SITES


1
2
3
5
ST
ICE
LEGEND
STUDY SITE BOUNDARY
2 AREA IDENTIFICATION NUMBER
▲ SAMPLING STATION
SCALE - 1" = 500'

Source: SEWRPC.

of the chemical processes which occur in the lakes and streams. Summer mean temperatures usually range from 68°F to 73°F. Northern lakeshore locations exhibit lower monthly mean summer temperatures than southern inland locations. Winter mean temperatures usually range from 19°F to 26°F.

Annual total precipitation is approximately 31.3 inches (water equivalent). Average annual snowfall is about 44.5 inches. Average total monthly precipitation for southeastern Wisconsin ranges from 1.29 inches in December to 3.77 inches in June. The principal snowfall months are December, January, February, and March, when average monthly snowfalls are 9.2, 11.9, 8.9, and 9.7 inches, respectively. Eighty-nine percent of the average annual snowfall may be expected during these months. Approximately 20 inches, or two-thirds of the average annual precipitation, normally occurs during the late April through mid-October growing season. Assuming that 10 inches of measured snowfall is equivalent to one inch of water, the average annual snowfall of 44.5 inches is equivalent to about 4.5 inches of water. Therefore, only about 19 percent of the average annual total precipitation occurs as snowfall. Approximately three-quarters of the 31.3 inch average annual precipitation is lost as evapo-transpiration; the remaining one-quarter is transported as streamflow.

Extreme event precipitation data for southeastern Wisconsin are presented in Table II.9. The minimum reported annual precipitation within southeastern Wisconsin occurred at Waukesha in 1901, when only 17.3 inches of precipitation occurred, or 55 percent of the average annual precipitation value. The maximum reported annual precipitation in southeastern Wisconsin occurred at Milwaukee in 1876, when 50.36 inches of precipitation occurred, equivalent to 161 percent of the average long-term annual precipitation value. The maximum monthly precipitation measured in southeastern Wisconsin was 13.17 inches, which occurred at West Bend in August 1924. The maximum 24-hour or daily precipitation ever recorded in southeastern Wisconsin was in the West Bend area on August 4, 1924, when 7.58 inches of rain fell.

Study Period Precipitation

Long term (1954-1981) and study period (1980-1981) total precipitation information for observation stations in West Allis and Mt. Mary College in Milwaukee is presented in Table II.10. These stations were chosen due to their proximity to the study sites, as shown on Figure II.2-3. During 1980 and 1981, annual precipitation at West Allis totalled 35.57 inches and 32.58 inches, respectively (4.46 inches and 1.47 inches or 14 and 5 percent, above normal). Annual precipitation at Mt. Mary College during 1980 and 1981 was 30.03 inches and 31.29 inches, respectively (0.78 inches, or 2 percent, below normal and 0.38 inches, or 1 percent, above normal).

Rainfall Intensity-Duration-Frequency Relationships

Rainfall intensity-duration-frequency (I-D-F) relationships are an important element in the design of stormwater management systems. These relationships compare average rainfall intensities, durations, and recurrence intervals. Under its comprehensive watershed planning program, the Southeastern Wisconsin Regional Planning Commission has developed a set of rainfall I-D-F relationships. The data, collected by the National Weather Service at

Table II.9

SELECTED EXTREME PRECIPITATION EVENTS IN SOUTHEASTERN WISCONSIN: SELECTED YEARS 1870-1981

Observation Station		Period of Precipitation Records Except Where Indicated Otherwise	Total Precipitation (Inches)						
			Maximum Annual		Minimum Annual		Maximum Monthly		
Name	County		Amount	Year	Amount	Year	Amount	Month	Year
Mitchell Field....	Milwaukee	1870-1980	50.36[a]	1876	18.69[a]	1901	10.03	June	1917
Racine............	Racine	1895-1980	48.33	1954	17.75	1910	10.98	May	1933
Waukesha..........	Waukesha	1892-1980	43.57	1938	17.30	1901	11.41	July	1952
West Bend.........	Washington	1922-1980	40.52	1938	19.72	1901	13.14[b]	August	1924
West Allis........	Milwaukee	1954-1981	42.85	1960	17.49	1963	9.63	June	1954
Mt. Mary College..	Milwaukee	1954-1981	41.25	1965	18.50	1963	10.17	June	1968

[a] Based on the period 1841-1980.

[b] Based on the period 1895-1959 in A Survey Report for Flood Control on the Milwaukee River and Tributaries, U. S. Army Engineer District, Chicago, Corps of Engineers, November 1964.

Source: U. S. Army Corps of Engineers, National Climatic Center, Wisconsin Statistical Reporting Service, and SEWRPC.

Table II.10

LONG TERM (1940-1979) PRECIPITATION DATA FOR THE MITCHELL FIELD OBSERVATION STATION MILWAUKEE, WISCONSIN

Month	Average Number of Events	Average Inches Per Event[a]	Average Hours Per Event	Average Inches Per Hour Per Event[a]
January	5.2	0.29	9.5	0.03
February	5.1	0.24	8.8	0.03
March	7.2	0.33	8.8	0.04
April	8.5	0.35	6.9	0.05
May	8.6	0.32	5.6	0.06
June	8.8	0.42	4.5	0.09
July	7.0	0.45	4.2	0.11
August	6.9	0.41	4.2	0.10
September	6.1	0.41	5.4	0.07
October	5.5	0.32	6.8	0.05
November	6.1	0.34	8.2	0.04
December	5.6	0.31	9.5	0.03

[a] Expressed as water equivalent.

Source: National Climatic Center and SEWRPC.

Mitchell Field in Milwaukee, are shown in Table II.11 and Figure II.11. The I-D-F equations resulting from the analysis of the Milwaukee data are presented in Table II.12. The I-D-F relationships shown in Table II.11 are based on a frequency analysis of Milwaukee rainfall for the 64-year period from 1903 through 1966. These I-D-F relationships are only applicable to the Milwaukee area. Spatial variations of I-D-F relationships occur in southeastern Wisconsin and can be large. The intensities increase in a southwesterly direction across the region, for constant recurrence intervals and durations.

Determination of Rainfall and Runoff Volumes

Rainfall and stormwater volumes for a given storm are used in assessing urban runoff impacts and control measures. The determinations of annual maximum precipitation event volumes were based on about 37 years of hourly precipitation data (from January 1, 1940 through October 31, 1976) recorded at General Mitchell Field.

Because of the importance of the minimum inter-event dry period used to define precipitation events, the 37-year precipitation record was analyzed using a range of dry periods. The number, time of occurrence, and depth of precipitation events during this period were determined using minimum inter-event dry periods of 1, 2, 3, 6, 12, and 24 hours. This range was selected to encompass periods of time likely to be of interest in analyzing catchment response.

Table II.13 presents the number of events greater than 0.01 inches of rain in 37 years, the average number of events per year, the depth of the largest events, and the depth of the median event for each of these six minimum lengths of inter-event dry periods. The total number of events in 37 years and the average number of events per year decreases as the minimum length of the inter-event dry period increases. Also, the volume of the largest event during the 37-year period increases as the minimum inter-event dry period increases. For example, using a minimum inter-event dry period of one hour, an average of 182 events per year occur, with the largest event having a depth of 3.42 inches. When the minimum inter-event dry period is increased to 24 hours, the number of precipitation events decreases 58 percent to an average of 77 per year, and the magnitude of the largest event increases by 81 percent to 6.20 inches. For a given recurrence interval, Figure II.12 indicates that the associated depth and volume of precipitation increases as the minimum inter-event dry period increases. For example, for a recurrence interval of five years, the precipitation depth associated with a minimum inter-event dry period of one hour is about 2.7 inches, while the precipitation depth associated with a minimum inter-event dry period of 24 hours is about 4.1 inches.

Table II.13 indicates that for a minimum inter-event period in the 12- to 24-hour range, there have been approximately 3,100 precipitation events during the 37-year period for which hourly precipitation data were available. Approximately 99.5 percent of those precipitation events were less than 3.8 inches.

Table II.11

POINT RAINFALL INTENSITY-DURATION-FREQUENCY DATA FOR MILWAUKEE, WISCONSIN[a]

Recurrence Interval (Years)	Duration and Intensity[b]						
	5 Minutes	10 Minutes	15 Minutes	30 Minutes	1 Hour	2 Hours	24 Hours
2..........	4.32	3.40	2.89	1.93	1.16	0.70	0.098
5..........	5.55	4.55	3.79	2.57	1.57	0.95	0.135
10..........	6.37	5.31	4.38	3.00	1.84	1.12	0.160
25..........	7.40	6.27	5.13	3.54	2.19	1.33	0.191
50..........	8.17	6.98	5.69	3.94	2.44	1.48	0.215
100..........	8.93	7.68	6.23	4.34	2.70	1.64	0.238

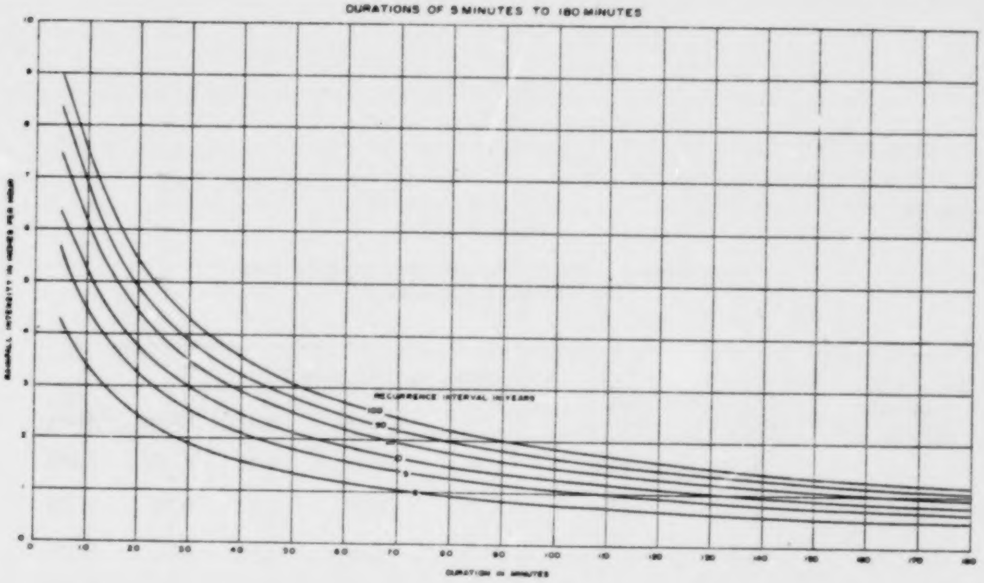
[a] These data are based on a statistical analysis of Milwaukee rainfall data for the 64-year period of 1903 to 1966.

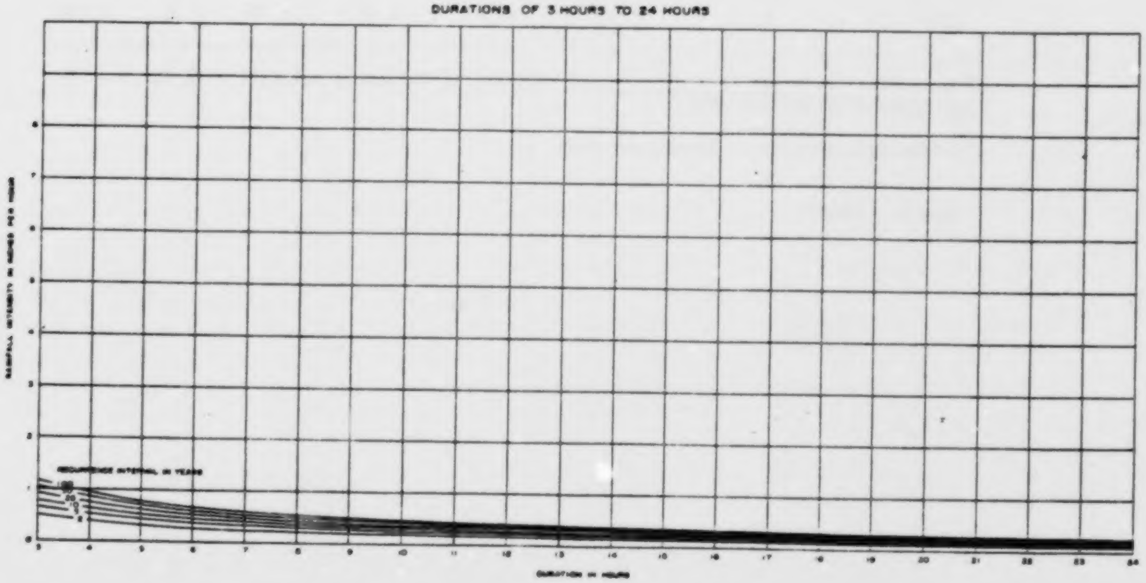
[b] Intensity expressed in inches per hour.

Source: SEWRPC.

Figure II.11

POINT RAINFALL INTENSITY-DURATION-FREQUENCY RELATIONSHIPS
FOR MILWAUKEE, WISCONSIN





Source: SEWRPC

H0103/0

Table II.12

POINT RAINFALL INTENSITY-DURATION-FREQUENCY EQUATIONS FOR MILWAUKEE, WISCONSIN[a]

Recurrence Interval (Years)	Equation[b]	
	Duration of 5 Minutes or More But Less Than 60 Minutes	Duration of 60 Minutes or More Through 24 hours
2........	$I = \frac{87.5}{15.4 + T}$	$I = 28.9\ T^{-0.781}$
5........	$I = \frac{120.2}{16.6 + T}$	$I = 38.2\ T^{-0.776}$
10.......	$I = \frac{141.8}{17.1 + T}$	$I = 44.2\ T^{-0.772}$
25.......	$I = \frac{170.1}{17.8 + T}$	$I = 52.3\ T^{-0.771}$
50.......	$I = \frac{190.1}{18.0 + T}$	$I = 57.3\ T^{-0.768}$
100.......	$I = \frac{211.4}{18.4 + T}$	$I = 63.5\ T^{-0.768}$

[a] The equations are based on Milwaukee rainfall data for the 64-year period of 1903 to 1966. These equations are applicable, within an accuracy of ±10 percent, to the entire Southeastern Wisconsin Planning Region.

[b] I = Rainfall intensity in inches per hour.
T = Duration in minutes.

Source: SEWRPC.

Table II.13

SELECTED INFORMATION ABOUT PRECIPITATION EVENTS AS DEFINED USING MINIMUM ANTECEDENT AND SUBSEQUENT DRY PERIODS OF 1, 2, 3, 6, 12, AND 24 HOURS[a]

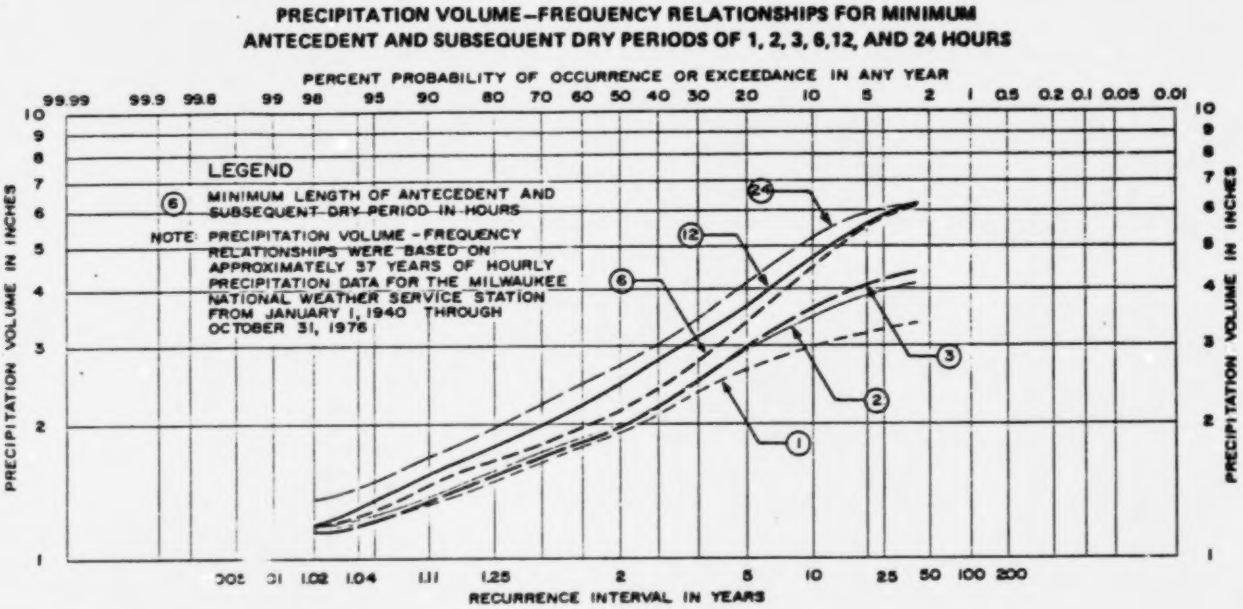
Minimum Antecedent and Subsequent Dry Period (Hours)	Number of Precipitation Events		Smallest Event (inches)	Largest Event (inches)	Median Event (inches)
	In 37 Years	Average Per Year			
1.........	6,719	182	0.01	3.42	0.04
2.........	5,577	151	0.01	4.16	0.06
3.........	5,008	136	0.01	4.31	0.07
6.........	4,147	113	0.01	6.05	0.10
12.........	3,458	94	0.01	6.20	0.14
24.........	2,842	77	0.01	6.20	0.19

[a] Based on approximately 37 years of hourly precipitation data for the Milwaukee National Weather Service Station from January 1, 1940, through October 31, 1976.

Source: National Climatic Center and SEWRPC.

Figure II-12

PRECIPITATION VOLUME-FREQUENCY RELATIONSHIPS FOR MINIMUM ANTECEDENT AND SUBSEQUENT DRY PERIODS OF 1,2,3,6,12,and 24 HOURS



Source: SEWRPC

CHAPTER III
MATERIALS AND METHODS

INTRODUCTION

The monitoring program for the Milwaukee NURP project is described in this chapter. Volume I summarizes the data and conclusions from this data. The monitoring program was very extensive and was carefully designed and executed to satisfy the many project objectives. Past Milwaukee data collection efforts were reviewed and also affected the specific experimental design. The purpose of the monitoring program was therefore to obtain site specific data addressing many aspects of urban runoff that had not been adequately examined previously.

Most of the monitoring effort obviously involved characterizing urban runoff from the eight study areas, under a variety of street cleaning conditions. Street dirt load were also monitored to supplement this information. Other source area monitoring efforts included rooftop runoff monitoring and atmospheric dustfall and precipitation quality and quantity monitoring. A quality assurance program supported this effort and is described in Chapter VI.

This chapter describes the experimental design, sample collection, sample processing, and laboratory analysis aspects of the urban runoff quality and flow monitoring, street dirt monitoring, wet and dry atmospheric deposition monitoring, and rooftop monitoring portions of this project. The data collected is summarized in Volume I, while complete data records are available from the WDNR. Much of the data is included in the U.S. EPA's STORET water quality data management system.

WATER QUALITY MONITORING

The experimental design of the stormwater monitoring effort was used to balance project objectives and resources. The objectives of the other monitoring elements (and associated data), such as street dirt loading and atmospheric deposition tests needed also to be considered. The available data from past monitoring projects was helpful. The scope of the monitoring effort was therefore defined when all of these aspects were considered. This discussion summarizes these aspects.

Stormwater from eight paired basins, representing four distinctive land uses, was monitored to characterize urban stormwater quality and to evaluate the water quality impact of street sweeping. One site in each pair was designated as the test site, (with varying street cleaning), and the other the control site (with constant, normal, street cleaning). The site names and respective land uses are:

Land Use	Control Site	Test Site
Commercial Strip	Wood Center	State Fair
Medium Density Residential	Burbank	Hastings
High Density Residential	Lincoln	Congress
Parking Lots	Post Office	Rustler

The eight study basins were all storm-sewered drainage systems with available monitoring sections of circular concrete pipes between 30 and 42-inches in diameter. Marsh-McBirney Model 250 Flowmeters were used to monitor discharge rates. This flowmeter uses an electromagnetic sensor and an air bubbler-pressure transducer to measure velocity and depth. An internal processor uses these input values to compute the discharge which is given as a 4 to 20 milliamp analog signal. This signal is directed to an Enviro Labs System 7 servo control which translates the analog signal to a digital signal to a Leopold & Stevens 16-channel paper-tape recorder. Runoff data were recorded at 1-minute intervals.

Manning S-4050 Suspended-Sediment Samplers were used to collect storm-runoff samples. These samplers use a vacuum pump and metering chamber to draw and measure the sample volume. The sampler can be activated either by time or flow pulse and can deposit from 1 to 10 subsamples in each of 24 bottles. The samplers were modified to produce a 12-volt, 10 amp signal for recording on a separate event recorder. The samplers were mounted on the top of small refrigerators which contained distribution spouts and 24 one liter sample bottles.

Stormwater samples were collected on a flow proportional basis and composited, yielding a single mean concentration for each event. Stormwater quality was characterized at the various study sites, and factors affecting stormwater quality were evaluated in Volume 1. A comparison of test and control site concentrations during test and control periods provided an evaluation of street sweeping as a nonpoint source management practice.

Required Analytical Effort

When the above aspects are considered, it is obvious that as many storms as possible need to be analyzed during the project period. Monitoring of the same event in both the test and control sites simultaneously is especially important.

Table III.1 shows the water quality constituent analytical priorities, based on the available runoff and receiving water monitoring data. The primary category of constituents received the most attention, while the secondary and miscellaneous categories were analyzed less frequently, especially if not enough sample was available. The analysis of the samples was done by the Wisconsin State Laboratory of Hygiene. The analytical procedures are approved by the U.S. Environmental Protection Agency and have been summarized in a mannual by the Laboratory of Hygiene (Laboratory, 1980).

Stormwater Sampling Procedures

Collection of the stormwater samples from the samplers was made as soon as possible after the end of a rain event. The collection procedures were as follows:

Service Manning S-4050 sampler

- Cap and label all sample bottles.
- Fill out sample log sheet with data and sample number.

TABLE III.1

SCHEDULE OF CONSTITUENT ANALYSIS

Primaries (TS, SS, VSS, Cl, TP, COD, TPb, TZn, DP, BOD_5)

- Composite Samples:

  Submit one composite sample per station per event.

- Discrete Samples:

  Discrete samples are to be analyzed on one event per station per season, with six discrete samples per station. Discrete samples are to be analyzed on the first event each season with 12 or more sample bottles filled.

Secondaries ($NO_2 + NO_3$, KN, NH_3, DPb, MES)

- $NO_2 + NO_3$, KN, NH_3, DPb:

  Submit one composite sample per event from the test areas only (State Fari Park, Verona, Steak House, W. Hasting, 54th Street). Discrete samples from the test areas are to be analyzed for those events and on those samples that the primary parameters are to be analyzed for as discretes.

- Multi-element Scan:

  Submit one composite sample per station, but only for every other event.

Miscellaneous

- BOD-30:

  Submit a two-liter composite sample for each station, but only for every other event, providing that for such events at least four or more sample bottles have been filled.

- Fecals:

  Submit one grab sample per station per event whenever they can be collected.

- Record the above sequence number on the bottle cap labels.
- Remove sample bottles and replace with clean bottles.
- Turn controller switch to BOTTLE ADVANCE and position discharge nozzle over #1 bottle.
- Switch controller to FLOW mode.

Service Discharge and Flow Recorders

- Record event start time and date from digital clock under START BY - DATE - TIME - WT and CT on digital tape leaders.
- Drain any remaining water from accumulator cup in rain gage pipe and push RESET button on precipitation activator. System should revert to STANDBY (green light on).
- Record event and data and time as AC clock reading on tape leader under REMOVED BY - DATE - TIME - WT and CT. Also record digital tape last punch reading and time.
- Remove digital tapes from both discharge and rainfall recorders.
- Reset recorders and fill out tape leaders with STATION ID and START BY - TAPE TIME. For rain-gage tape, add GH-DIAL reading.

Service Event Marker

- Record starting and ending date and time on strip chart record.
- Count number of sample marks and record on event summary form.
- Remove strip chart record.

Service Bulk Rain Gage

- Remove rain gage collector from side of roof and record amount on event summary form.
- Drain and reinstall rain gage.

Fill out event summary form

Check that the following has been done before leaving station:

- Flow meter set to FLOW.
- Level trigger set to appropriate depth to prevent low flow sampling.
- Discharge and rainfall recorders reset with leaders filled out.
- Precipitation activator on STANDBY, coax cable inserted in collector cap.
- Sampler set to FLOW after BOTTLE ADVANCE was used to reset bottle counter.

When leaving the station the following items should be taken:

- Sample bottles in cooler.
- Sample log sheet.
- Discharge and rainfall digital tapes.
- Event marker strip chart.
- Event summary form.

Manning S-4050 Water Sampler

The Manning S-4050 sampler is a pressure/vacuum sampler which uses a chamber to measure the sample volume and an air and water purge system to prevent cross contamination of samples. The sampler has a solid state controller with time and function selection switches. Sampling can be initiated either by time mode or by flow mode (by momentary contact closure from an external flowmeter). An optional one liter sample capability was selected in order to obtain enough sample volume for analyses of the desired water quality constituents. The sampler has all operating components including controller, compressor, measuring chamber, and valves mounted to a single assembly made of ABS plastic. For portable applications, this assembly rests on top of an insulated bottle case which contains 24, one-liter sample bottles. The sampler has a multiple sample/multiple bottle selector switch which allows from one to ten samples to be deposited within a single bottle, or allows from one to ten bottles to be filled in rapid sequence. The sampler was set to put two samples in each bottle. An attempt was made to adjust the sample intake velocity to 3 ft/sec. The samplers were used in a flow-weighted mode during this study.

The following list summarizes the automatic sampling procedure:

a. An initial air purge sample is drawn up through the sample intake hose into the sample purge chamber.

b. The level sensor in the purge chamber is actuated, which reverses the system to flush the sample back out the intake hose.

c. The normal sample intake cycle then begins by drawing the sample up into the measuring chamber with a swirling (vortex) action.

d. After the chamber is filled to the volume desired, a pinch valve opens and the sample is deposited into a sample bottle through the spout assembly. A final air purge then occurs.

Installation of the S-4050 Sampler --
The S-4050 sampling unit was separated from the bottle base and mounted to the top of a 12.5 cu. ft. refrigerator. The refrigerator contained a rack with 24 one-liter sample bottles and an auxiliary distribution spout which was coupled to the sampler. The sampler was installed in 5'x5'x8' insulated, above ground, instrument shelter, and was powered by a 12 VDC, 10 amp power supply. A 12 VDC signal to a four-channel strip chart recorder indicated the time of each sample collection. The sampler was set to the flow proportionate sampling mode and was activated by a momentary switch closure from the flow-proportional sampling circuit of the Marsh McBirney Model 250 flowmeter.

The samplers used a 0.375 inch (I.D.) nylon-reinforced PVC sample intake hose attached by quick disconnect fittings to the sampler and routed to the storm sewer through a two inch diameter PVC pipe. Inside the storm sewer, the sample tubing was inserted in a one-inch diameter steel conduit which was anchored to the storm sewer. The sample tube orifice was positioned approximately three inches above the culvert invert and faced 30° downstream. The orifice was simply the end of the tube cut off parallel to the flow and projecting one inch beyond the end of the conduit.

Problems Encountered with the S-4050 Sampler --
The S-4050 sampler has a large number of components ranging from the solid state controller to solenoids and rubber "O" rings which needed attention during the 2-1/2 years they were in use. Reliable operation of the sampler required consistent attention by field personnel. The following problems were identified:

- To restart the internal bottle counter, the function control switch had to be set to BOTTLE ADVANCE. The operations manual had indicated that the OFF function would restart the bottle sequence.
- Rubber "O" rings around the measuring chamber had to be changed periodically.
- PVC fittings and couplings were not properly glued and resulted in numerous vacuum leaks.
- The pressure switch to control sample volume failed regularly until replaced after about 1-1/2 years by a less troublesome design.
- After rapid, short duration sampling, the pinch valve solenoid would fail. Replacement was expensive and time-consuming.
- Turnaround time for repair of components returned to the factory was excessive, and, as evidenced by the number of defects detected on the originally supplied samplers, the quality control of the manufacturer was not impressive.

The Manning S-4050 sampler can be effectively used to sample stormwater runoff. However, the large number of components required by this pressure/vacuum sampler do require frequent and thorough inspection. The testing instrument found to be most useful was a vacuum gage. This was used to detect low vacuum values and to confirm that the problem was corrected. The normal vacuum range for the samplers in use was from 18 to 21 inches of mercury.

Sampler Performance --
Tests were conducted to determine the maximum suction head to ensure adequate sample velocity in the sampling tube. The EPA recommends a minimum velocity of 3 ft/sec for suspended solids sampling, even though this velocity may not be adequate to accurately sample bed load. Table III.2 shows the results of these tests and indicates that a maximum head of 14 feet should be used.

Table III.2

INTAKE VELOCITY VS. HEAD HEIGHT IN MANNING AND ISCO AUTOMATIC SAMPLERS*

Head (ft)	Sampler	Time from Start of Suction Mode to Sampler (sec.)	Intake Velocity (ft/sec)	Volume Sampled (ml)
4	Manning	5.5	4.6	950
(max)	ISCO	6.0	4.2	550
7	Manning	5.8	4.5	950
	ISCO	6.5	3.8	550
11	Manning	7.2	3.5	925
	ISCO	7.8	3.3	470
13.5	Manning	8.0	3.1	900
	ISCO	7.8	3.3	470
16.5	Manning	10.7	2.3	-
	ISCO	8.9	2.8	350

*Constants: 25 feet hose length, maximum pressure setting.

Stormwater Sample Processing

After collection of runoff samples at individual monitoring stations, the cooled samples were taken to the Southeast District DNR Lab. Each set of samples were then processed as follows (a "set" represents all of the flow proportionate samples taken during one rain event at one station):

All one liter samples in a set were "split" and composited using a DECA splitter (Figure III.1). The resulting composite consists of a one liter flow proportionate sample representing the entire event. The splitter was developed and tested by the USGS Quality of Water Branch (refer to Quality of Water Branch Technical Memorandum No. 80.17).

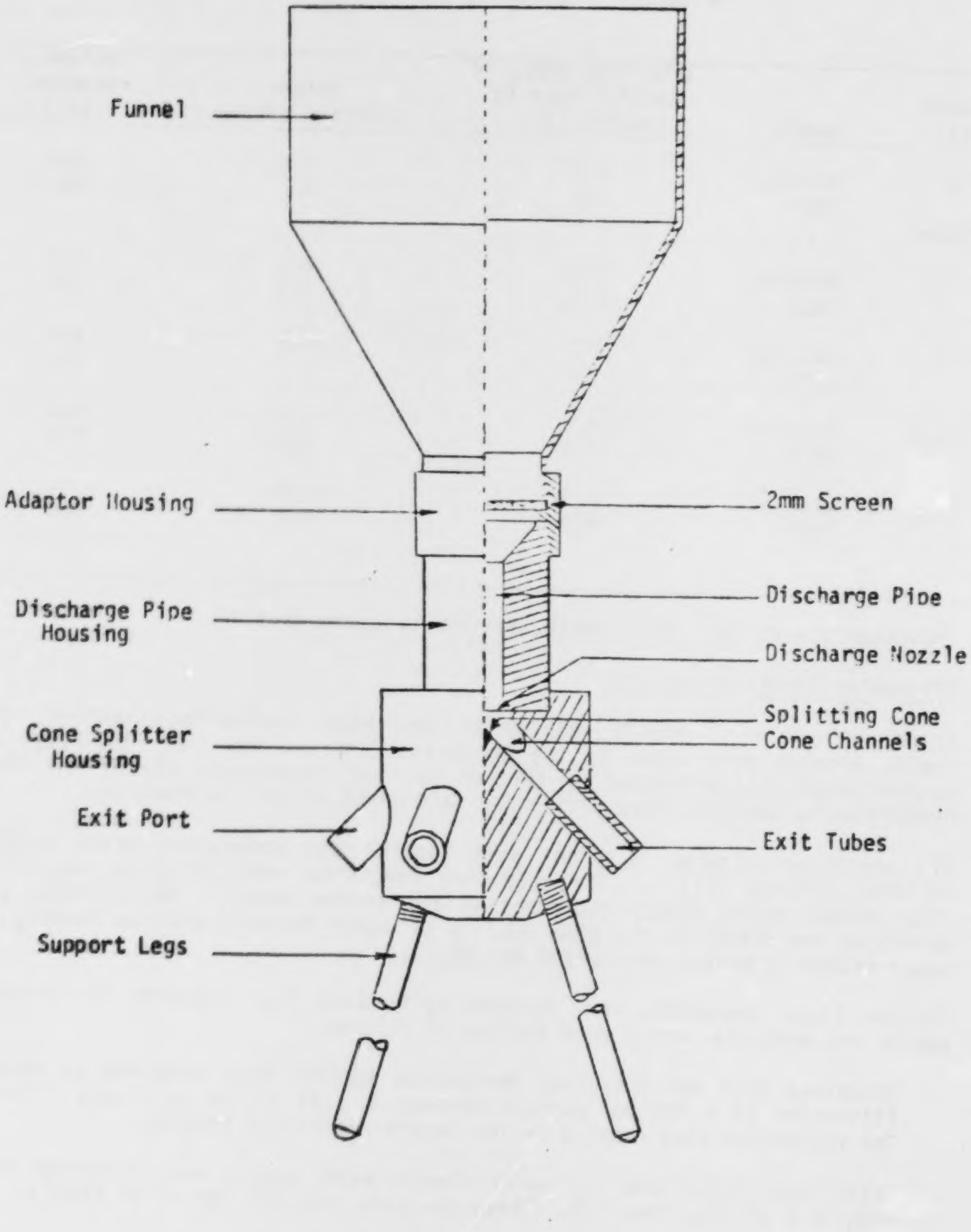
The one liter composites were further split into four allquots for preservation and analysis, which were treated as follows:

- Dissolved Lead and Dissolved Phosphorus samples were obtained by vacuum filtration of a 100 ml portion through a 0.45 micron millipore filter. The filtration step results in two separate filtered samples.

- Total lead, total zinc and multi-element scan samples were acidified with HNO_3 to a pH less than 2.0. These analyses required 100 ml of sample.

FIGURE III.1

DECA SAMPLE SPLITTER


Funnel
Adaptor Housing
2mm Screen
Discharge Pipe Housing
Discharge Pipe
Discharge Nozzle
Cone Splitter Housing
Splitting Cone
Cone Channels
Exit Port
Exit Tubes
Support Legs

- Total phosphorus, nitrite plus nitrate-N, Kjeldahl-N, ammonia-N, and COD samples were preserved with sulfuric acid (2.4 ml 12.5% acid per 300 ml sample). A re-pipet with an adjustable volume selector was used for acid addition. These analyses required 300 ml of sample.
- Chlorides, suspended solids, total solids, and volatile suspended solids required no further treatment other than cooling. These analyses required 500 ml of sample.

The analysis schedule included primary, secondary, and less frequently analyzed constituents as previously described.

The lab procedures were divided into three activities: record-keeping, sample-splitting, and sample filtration. The procedures for each activity are described in the following paragraphs. To facilitate orderly operations in the lab, all information relating to runoff sample processing and recording was organized into manuals and was maintained at the DNR lab.

After processing, the samples were transported on ice to the State Lab of Hygiene in Madison, where they were refrigerated and subsequently analyzed. A detailed record keeping procedure was used to keep track of all samples processed.

Sample Splitting Procedure --
Combine the individual samples into one composite sample, and split that sample into four samples for analyses.

- Specifications for Bottles Sent to Laboratory:

Label Color	Sample	Sample Vol. Needed	Bottle Volume
White	A - Solids Cl, BOD_5	400 ml	625 ml
Yellow	A - N Series, TP, COD	300 ml	625 ml
Green	C - Metals, MES	100 ml	250 ml
White & Green	D - Filtrate	100 ml	250 ml

- Initial Split Into Composite Sample:

Total Sample Volume Collected, All Bottles	Number of Lines Into 2.5 Liter Bottle	Volume of Composite Sample
1.0 - 2.0 liters	N.A. - split directly into samples A-D	
2.0 - 3.0 liters	5	1.0 - 1.5 liters
3.0 - 4.0 liters	4	1.2 - 1.6 liters
4.0 - 5.0 liters	3	1.25 - 1.5 liters
5.0 - 10.0 liters	2	1.0 - 2.0 liters
10.0 - 24.0 liters	1	1.0 - 2.4 liters

- Final Split Into Three Bottles Sent To Laboratory And One For Filtration:

Sample A, White Label: Solids, Cl, BOD_5:

Composite Sample Volume	Number of Lines to Sample A	Sample A Volume
1.0 - 1.25 liters	5	500 - 625 ml
1.25 - 1.5 liters	4	500 - 600 ml
1.5 - 2.0 liters	3	450 - 600 ml
2.0 - 2.4 liters	2	400 - 480 ml

Sample B, Yellow Label: N. Series, TP, COD:

Composite Sample Volume	Number of Lines to Sample B	Sample B Volume
1.0 - 1.8 liters	3	300 - 540 ml
1.8 - 2.4 liters	2	360 - 480 ml

Add 8 ml of 12.5% H_2SO_4 per 100 ml of sample.

Samples C and D, Green and White Labels:

In all cases, use only one line to each of these bottles, to get sample volumes between 100 - 240 ml.

- Clean DECA splitter before initial use, between stations, and after the last station, following the splitter cleaning procedures.

DECA Splitter Cleaning Procedure--

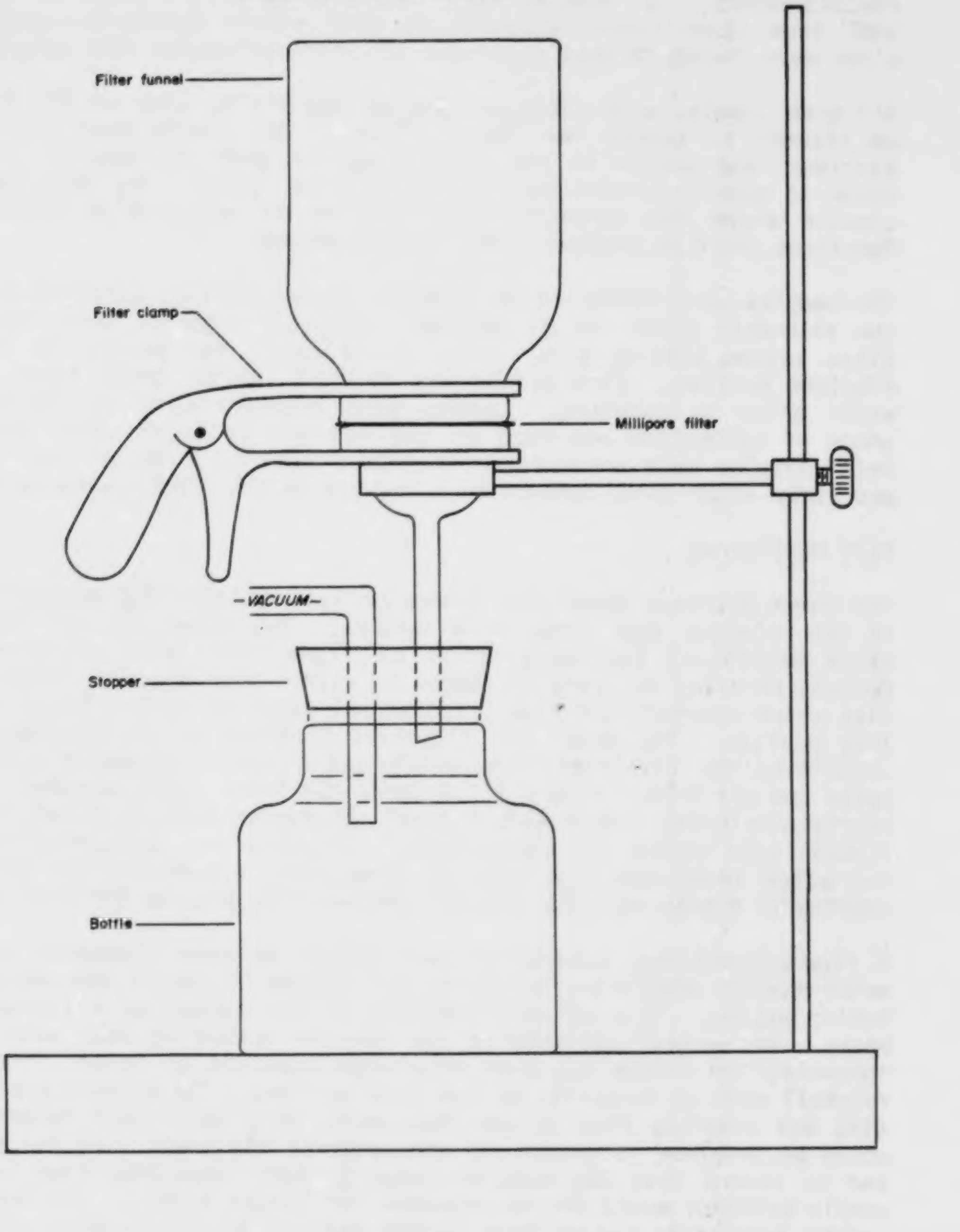
- Remove collector funnel, invert and back-flush with tap water from hose in sink.
- Place tap water hose tightly over splitter base inlet and rinse with tap water under pressure. If debris remains in base, remove with small nylon brush.
- Replace collector funnel and rinse entire assembly twice with 500 ml distilled water each time.
- Once a month, run distilled water blank through splitter. Record date on log sheet.

Sample Filtering Procedure --

Dissolved chemical constituents (e.g. dissolved ortho phosphorus) must be filtered through a 0.45 micron filter prior to analysis, to meet Federal Register requirements. The filtering apparatus made by Millipore Corp., Redford, Mass., (Figure III.2) was cleaned with 50 percent HCL and Milli-Q water prior to use. Before each sample the apparatus and the 0.45 Membrane Filter were used with 10 percent HCL and milli-Q water. The sample was vacuum filtered into a 60 ml polyethylene bottles.

FIGURE III.2

SAMPLE FILTERING DEVICE


Filter funnel
Filter clamp
Millipore filter
VACUUM
Stopper
Bottle

Special NURP Priority Pollutant Monitoring Procedures

The objective of the priority pollutant program was to determine which priority pollutants and metals exist in the Milwaukee NURP watersheds and in what concentrations. All samples were taken during a rain event on September 21, 1981 from storm sewers adjacent to NURP runoff monitoring stations. Four sites were chosen to best represent the eight Milwaukee NURP watersheds.

All grab samples were taken by hand on the rising limb of the hydrograph in an attempt to sample the "first flush". Two people were present at each station: one person in the storm sewer to grab the samples and the other above to supply bottles and record sampling times. The only exception was Lincoln where the sampling point was at an end-of-pipe outfall and all functions could be handled safely by one person.

The samples were collected in cleaned, sealed bottles supplied by RALTEC and the Wisconsin State Lab of Hygiene. Volatile organics were taken in 40 ml glass septum bottles with teflon lined caps; and metals in 250 ml polyethylene bottles. Each bottle was flushed two or three times with sample water prior to sampling. Samples were hand-delivered to RALTEC within 24 hours of collection and kept on ice and out of light until their arrival. Metal samples were preserved with nitric acid to a pH of less than two immediately after field collection according to EPA (1980) procedures.

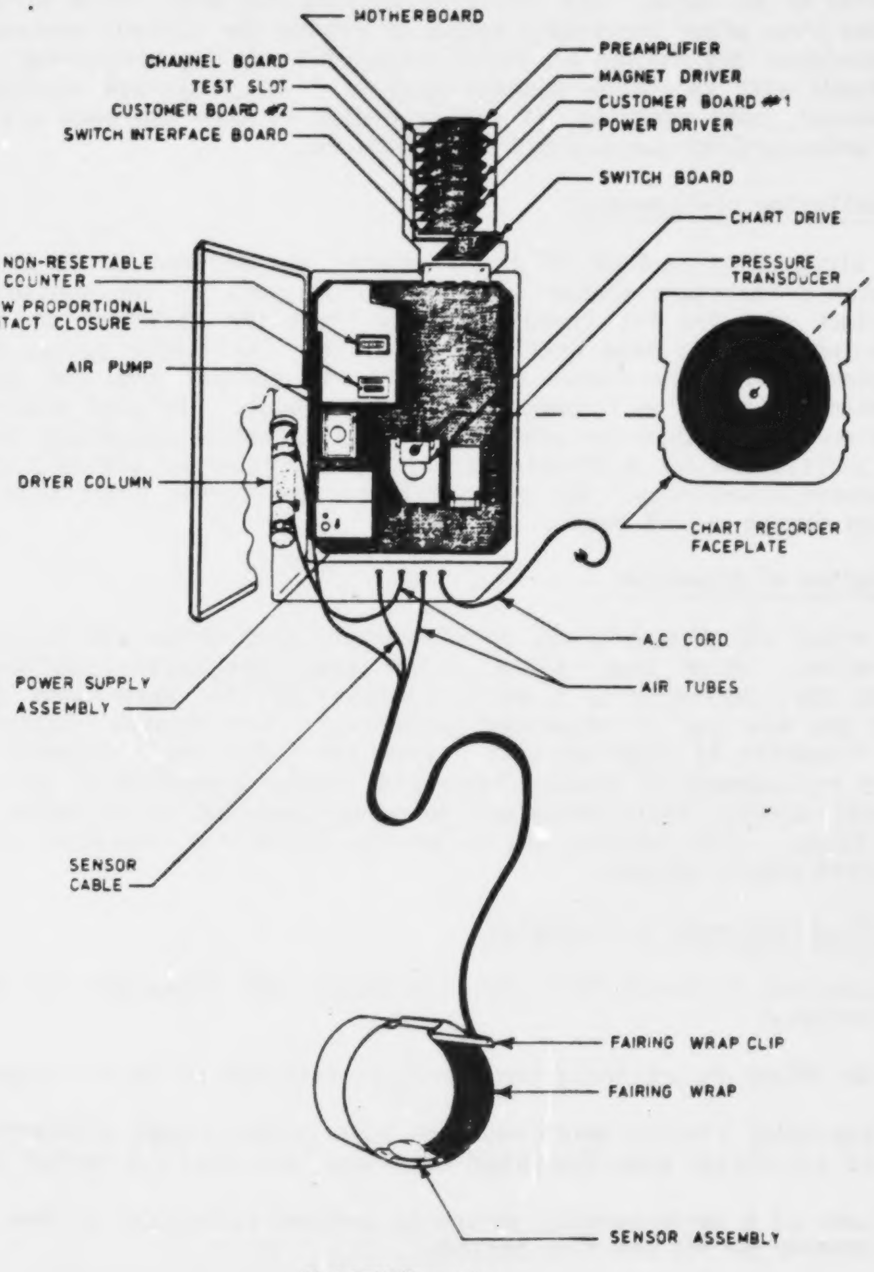
FLOW MONITORING

The Marsh McBirney Model 250 Flowmeter was selected for monitoring the flow at the selected NURP sites in Milwaukee. The sites all had limited access which prohibited the installation of flumes and level recorders. Limited funding required analysis of composite rather than discrete storm runoff samples which necessitated flow proportional sampling controlled by a continuous flow monitor. The Model 250 flowmeter consists of an instrument enclosure containing the electronic components and a sensor assembly with connecting cable and air hose. Figure III.3 shows the Model 250 flowmeter. An electromagnetic velocity sensor with a level transducer bubbler outlet is mounted to a steel band inside the storm sewer. Discharge was calculated by converting the water level and pipe size to flow area, converting the point velocity reading to a mean velocity and multiplying flow area by the mean velocity.

A flow-proportional contact closure switch on each flowmeter activated the water-quality samplers after a pre-set volume of runoff had passed the monitoring points. This allowed sampling of the events on a flow-proportionate basis. An initial estimate of the pre-set volume at each site was made by computing the volume and peak discharge expected to result from a 1.0-inch rainfall with an intensity of 0.6 inch per hour. An attempt was made at setting the sampling flow volume increments so a sufficient number of samples would be obtained to adequately characterize the event load for small events, and to insure that the sampler capacity (both recycling time and number of sample bottles) would not be exceeded for larger events. The initial pre-set sample increments ranged from 10,000 gallons at the Burbank site to 25,000 gallons at the Wood Center site. These values were modified after the first several months of recorded discharges so that the preset sampling volume increments ranged from 5,000 gallons at the Rustler site to 25,000 gallons at the Wood Center site.

FIGURE III-3

MARSH-MC BIRNEY MODEL 250 FLOWMETER


MOTHERBOARD
CHANNEL BOARD
TEST SLOT
CUSTOMER BOARD #2
SWITCH INTERFACE BOARD
PREAMPLIFIER
MAGNET DRIVER
CUSTOMER BOARD #1
POWER DRIVER
SWITCH BOARD
CHART DRIVE
NON-RESETTABLE COUNTER
PRESSURE TRANSDUCER
FLOW PROPORTIONAL CONTACT CLOSURE
AIR PUMP
DRYER COLUMN
CHART RECORDER FACEPLATE
A.C CORD
AIR TUBES
POWER SUPPLY ASSEMBLY
SENSOR CABLE
FAIRING WRAP CLIP
FAIRING WRAP
SENSOR ASSEMBLY

Model 250 Flowmeter

To prevent the recording of data during base-flow periods, a control system was designed which activated the recording circuits after 0.01 inch of rainfall. Upon activation, a 24-hour digital clock was started, marking the beginning of an event. The recording systems ran until field personnel arrived at the site after the events ended to return the control systems to standby. To minimize the number of field trips, two of the monitoring stations were equipped with telephone message systems. These systems informed the field personnel, upon querying, if the recording systems had been activated and if any water-quality samples had been obtained.

Installation of Flowmeter

The electronics package of the flowmeter was mounted in an above-the-ground insulated structure placed as close as possible to the monitoring site. A two-inch diameter PVC conduit was run from the structure to the top storm sewer which had a hole drilled through it. The sensor cable, air hose, and sampler tubing were routed through the PVC conduit from the stainless steel mounting band to the flowmeter instrument panel. The most restrictive siting requirement was that the sensor had to be installed where the flow was smooth and undisturbed for a distance of five pipe diameters upstream and three pipe diameters downstream. The eight selected monitoring sites had minimal flow, except during runoff events.

Operation of Flowmeter

The Model 250 flowmeter is an AC-powered unit which was designed for easy operation. Other than initial calibration, the major requirements were to check that the velocity probe and bubbler orifice were clear of debris and that the electronics responded properly to the internal calibration check. The flowmeter is supplied with a circular 7-day chart recorder which needed chart replacement at regular intervals. After operation of the flowmeter for several months, field personnel detected condensation of water vapor in the air tubes. This problem was solved by installing dessicant chambers which required weekly changes.

Modifications Made to Flowmeter

As supplied by Marsh McBirney, the Model 250 flowmeter had the following limitations:

- No method to prevent water vapor condensation in the air tubes.
- Low-level circuit which resulted in a preset signal indicating a velocity of 4.0 ft/sec when the water level was less than 2.5 inches in depth.
- Lack of a depth-sensing switch to prevent activation of the water-quality sampler during low-flow periods.
- Susceptibility to electrical damage from voltage surges due to lightning strikes near power lines.
- The 4 to 20 mA signal output circuit was not electrically isolated from the external recording system, causing a ground loop between the velocity probe and the System 7 servo control.

- The bubbler orifice located on the sensor head mounting plate was in an area of turbulence created by velocities in excess of 6.0 ft/sec. This resulted in drawdown at the orifice and inaccurate depth sensing.

The condensation within the air tubes was from ambient air pumped by an electrical diaphragm pump into the inlet air tube. A 2" x 10" drying column was installed and filled with an indicator dessicant which dried the air to a newpoint of -100°F. Experience showed that the dessicant had to be replaced weekly. Without the drying tubes, the collected condensate would prevent the depth from being accurately sensed by the pressure transducer.

The Model 250 flowmeter was factory adjusted to deliver a output signal indicating a velocity of 4.0 ft/sec when the flow depth sensed was less than 2.5 inches. This signal incorrectly indicated the instantaneous flow rate (too high) for low-flow periods. The problem was not detected until several months into the study, and the required adjustments to indicate a flow of 0.0 ft/sec velocity at zero stage levels were not completed until November of 1980.

The Model 250 flowmeter was equipped with an adjustable flow-proportionate contact closure circuit which would activate the Manning S-4050 water-quality sampler. During low-flow periods, the Model 250 flowmeter would accumulate flow and eventually trigger the sampler, thereby reducing the number of sample bottles available for storm events. A level actuator system was locally designed and installed, which allowed the flow-proportionate contact closure circuit to be deactivated until the depth equaled a set level. The usual practice for those sites without backwater problems was to set the level trigger at approximately 10 percent of the pipe diameter. This practice eliminated much of the nuisance sampling, but small events could not be sampled easily.

The failure rate during the first year of the project for the Model 250 flowmeter after thunderstorms was high. Each flowmeter had to be returned to the factory about two times for repair due to electrical damage. The problem seemed to be caused by voltage surges due to lightening strikes near the power lines. Each flowmeter was subsequently equipped with a voltage surge protector, and the failure rate was greatly reduced.

A problem which was not solved until after the data collection was completed was the dissolution of the upstream carbon electrode on the velocity probe. At least four of the eight velocity probes had to be replaced due to damage to this electrode. The cause was originally diagnosed as abrasion from sand and grit carried with the storm runoff. The actual cause was an electrical ground loop between the external recorder and the velocity probe causing galvanic corosion. Marsh McBirney resolved this problem by inserting a self-powered 4 to 20 mA isolation transformer between the extra System 7 servo control and the 4 to 20 mA output circuit from the flowmeter. Testing during June 1983 of an isolation transformer manufactured by Rochester Instrument Systems showed satisfactory results.

The air pressure transducer bubbler orifice located on the sensor head mounting plate as supplied by Marsh McBirney did not appear to function well at velocities greater than 6 ft/sec. Turbulence induced by the mounting band

and the sensor head created a pressure sensed by the bubbler not equal to the static pressure (Schneider, 1979 and Moss, 1981). Testing was performed by the USGS Hydrologic Instrumentation Facility Instrument Development Laboratory to determine the extent of the problem and to develop corrective procedures. The original testing results reported in a memorandum to the USGS Surface Water Branch, dated March 30, 1979, found that the bubbler-indicated depths for velocities greater than 6 ft/sec were consistently lower than for piezometer-indicated depths 12 inches upstream of the mounting band. Subsequent testing by the USGS confirmed the above velocity-induced depth-sensing error and recommended that the bubbler orifice be disconnected from the velocity probe and moved 6 to 12 inches upstream, or downstream, from the probe and located perpendicular to the flow to minimize drawdown or pileup (Moss, 1981).

Based upon the above recommendations, all Milwaukee NURP sites experiencing velocities greater than 6.0 ft/sec were modified by extending the bubbler orifice ten inches downstream and perpendicular to the flow. These modifications were completed during March 1981 and were maintained until February 1982. During the 1981 runoff season, the Model 250 flowmeter flow values seemed low, but due to the quick response of the basin and dryer-than-usual conditions, few verification checks were able to be made on the accuracy of the recorded discharges.

During August 1981 a two-channel strip chart recorder was installed at the Wood Center site. The recorder was set to record the flowmeter depth and velocity signals. With the strip chart record and several dye-dilution discharge measurements, it was possible to determine that the water-level detection system of the flowmeter was still sensing less than the actual depth. Additional information from the USGS Hydrologic Instrumentation Facility indicated that the flowmeter performed better when the bubbler orifice was oriented parallel to the flow and facing in a downstream direction. This modification was then made at all sites. As determined from dye-dilution discharge measurements, depth and velocity strip chart recordings, and independent depth measurements, this last modification resulted in much more reliable depth-sensing by the Model 250 flowmeter.

Calibration of the Flowmeter

Studies made by the USGS Hydrologic Instrumentation Facility emphasized the need for in-place calibration of the Model 250 flowmeter (Schneider, 1979 and Moss, 1981). Measured discharges can be in error by as much as 60 percent, or more, without calibration. The following procedure for checking the depth-measuring system was developed for situations where the flowmeter could not be calibrated while installed in a storm sewer.

- Disconnect the power to the VMFM meter.
- Remove the plate underneath the circular chart on the front of the recorder.
- Locate and remove a hold-down screw which locks down a large plate which occupies the upper right quarter of the meter.

- Rotate large plate upward 90° and support in raised position.
- Repower the VMFM.
- Install sensor in the bottom of a trash can.
- Add water to trash can and measure depth at sensor using a staff gage section; record the percent level indicated by the VMFM and the measured depth. Convert percent level to depth.
- Repeat step g for an appropriate range of depths.
- Plot actual depth vs. VMFM depth and determine if VMFM pressure transducer needs adjustment. (In many cases, the percent level does not follow the correct water level, and adjustment to the slope and zero of the pressure transducer are necessary.)
- Locate pressure transducer. Two plastic hole covers must be removed from the top of the pressure transducer (refer to Figure III.3).
- Adjustments to pressure transducer for slope, S, and zero, Z, are made through the appropriately marked holes.
- Check level in trash can at several points to ensure that VMFM is properly adjusted.
- Remove sensor from trash can, disconnect power to VMFM and reassemble meter.

The velocity probe component of the Model flowmeter seemed to work quite well. A potential problem with the velocity probe is the adjustment factor necessary to convert point velocity to average velocity. It probably is not a constant for the full range of flows.

When the Model 250 flowmeter has to be located such that personnel cannot get to the sensor head during high flows to measure depth and velocity, it is recommended that dye-dilution discharge measurements be made to calibrate the flowmeter. The variability in discharge with time and the short duration of flow within the small, highly impervious basins required the use of an automated dye-dilution injection system (Duerk, 1983). Dilution gaging has been used successfully in open-channel conditions (Rantz, et. al., 1982), and the procedures used in closed conduits was based upon that work. Calibration of the flowmeters for low flow conditions was completed during 1981, using constant discharges from the city fire hydrants. The calibration consisted of recording the flow meter depth, velocity and discharge signals. The independent velocity and depth measurements consistently showed a higher discharge. This was traced to the presence of chlorine in the city water supply which had the effect of oxidizing the Rhodamine WT dye. These decreases in the dye concentrations resulted in higher than actual discharge values. The independent velocity and depth measurements compared closely with the Marsh-McBirney measurements, but these were for discharges up to 6 cfs. The concern with the accuracy of the flow meter existed for deeper flow depths and resultant faster velocities. The difficulties experienced in using the dye-dilution injection method with city water supplies was not present with storm runoff. The automatic dye-injection system was set up as follows:

- A constant rate injection pump and dye reservoir was suspended in a manhole a sufficient distance upstream to assure complete mixing of the dye before reaching the water-quality sampler intake.
- The injection pump was connected to a level-detection switch on the Model 250 flowmeter and activated when the desired water depth was reached. It would also be deactivated when the depth fell below the desired level.
- Both the injection pump and the water-quality sampler were wired to an event recorder which marked the on/off times for the pump and the times of sampling by the sampler. The sampler was controlled by the flow-proportional contact closure system of the Model 250 flowmeter.
- Samples taken by the water-quality sampler during dye injection tests were taken to a lab where the dye concentrations were determined using standard fluorometric techniques (Hubbard, et. al., undated). The dye-injection rate, initial dye concentration, and the dye concentration in the runoff sample were used to compute the flow rate for each discrete runoff sample.

These dye tests were conducted at four of the monitoring locations (Wood Center, State Fair Park, Lincoln Creek, and Rustler Steak House). The injection pump location ranged from 75 feet upstream of the sampler intake at the Lincoln Creek site to 520 feet upstream at the Rustler Steak House site. The largest number of storms measured with dye dilution (four) occurred at the Wood Center site. At this site, the percent difference between the dye-injection discharge rate and the flowmeter rate ranged from -56 percent to +38 percent with a mean difference of -14 percent. Table III.3 shows a comparison of the analyzed dye-injection flow rate and the Model 250 flow rate for the April 16, 1982 storm at the Wood Center site. Figure III.4 is the discharge hydrograph for the storm runoff and includes the discharge signal value sent to the external recorder by the Model 250, the discharge computed from the depth and velocity values recorded on a 2-channel strip chart recorder, and the discharge computed from the dye-dilution analyses. The greatest difference between the dye-dilution discharge and the Model 250 flowmeter discharge occurred during rapidly changing flow rates. Duerk (1983) found similar results during the rising limb (with rapidly changing flows). The greatest differences for the other tests also occurred on the rising limb of the hydrograph.

Recommendations for the Use of the Model 250 Flowmeter

The Marsh McBirney Model 250 flowmeter appears to be a usable instrument for monitoring discharge in closed conduit systems. The following recommendations should be followed to obtain the best possible accuracy and reliability from the unit:

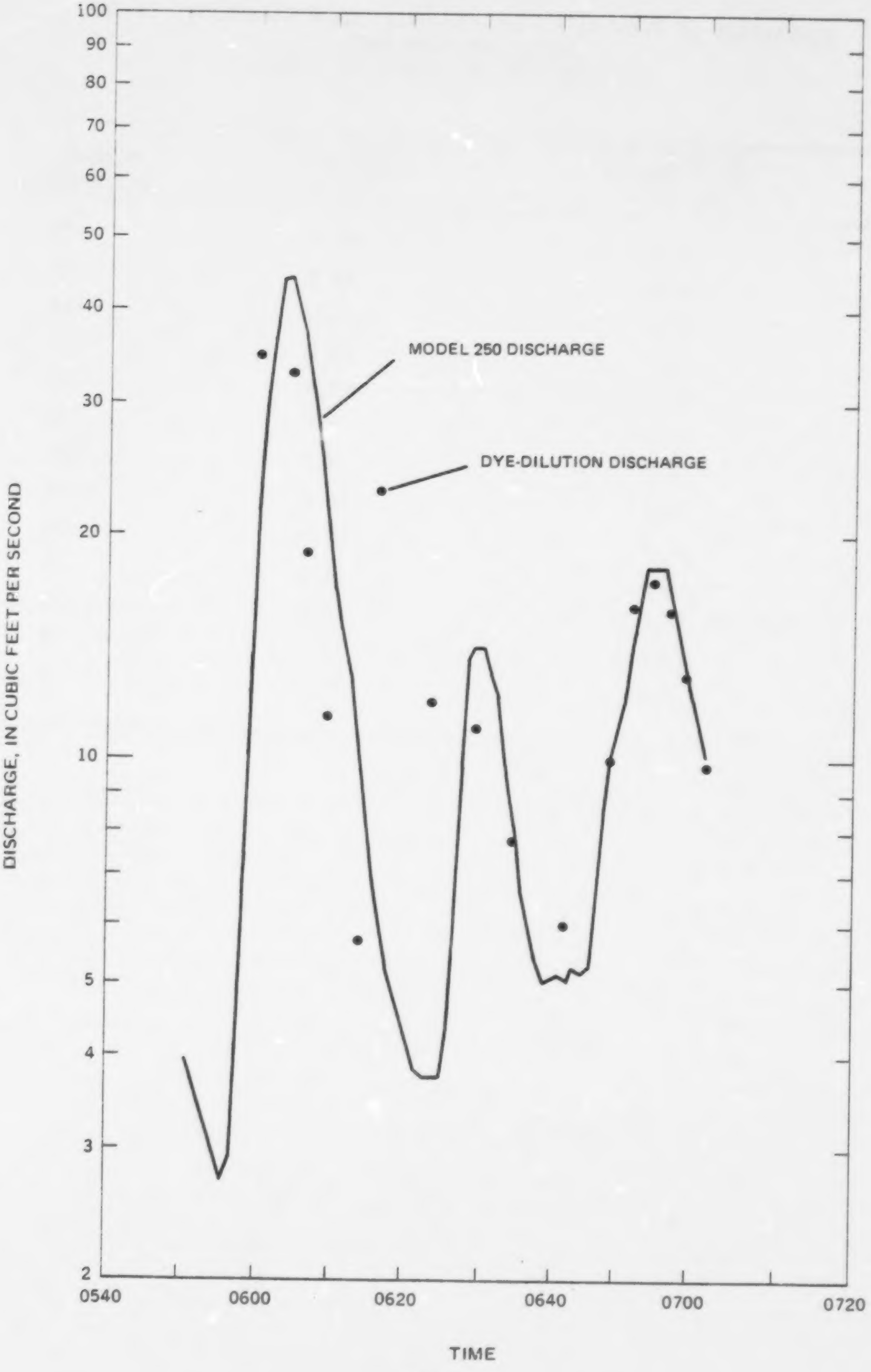
- Equip the Model 250 with a voltage surge protector to prevent electrical damage from voltage spikes.

TABLE III.3

COMPARISON OF FLOW RATE FROM DYE-DILUTION MEASUREMENTS TO THE MODEL 250 FLOW RATE FOR WOOD CENTER, APRIL 16, 1982

Time 24-Hr.	Discharge from Dye-Dilution (ft^3/s)	Discharge from Model 250 (ft^3/s)	Percent Difference
0603	32.7	44.0	-26
0605	18.8	44.0	-54
0608	11.4	25.0	-54
0612	5.7	13.0	-56
0628	11.1	13.0	-15
0634	7.8	8.1	-4
0640	6.0	5.1	+18
0647	10.2	10.0	+2
0649	16.3	12.0	+36
0652	16.9	18.0	-6
0654	15.9	18.0	-12
0656	12.6	15.0	-8
0659	9.8	10.0	-2

FIGURE III-4
COMPARISON OF DYE-DILUTION DISCHARGE VERSUS MARSH-McBIRNEY MODEL 250 DISCHARGE FOR APRIL 16, 1982 AT WOOD CENTER SITE (04087133)



- In areas of high relative humidity, use a dessicant column to prevent condensation in the air tubes.

- Perform the depth calibration prior to installation of the sensor probe in the storm sewer.

- If the 4 to 20 milliamp signal output circuit is used for recording discharges, install an isolation transformer between the Model 250 and the external recorder.

- If flow-proportional sampling is to be attempted, install a level-sensing switch to prevent sampling at low flows.

- Remove the bubbler orifice from the sensor head, extend it 12 inches upstream of the mounting band, and orient the orifice parallel to the flow facing downstream.

- Calibrate the Model 250 for low, medium, and high flow rates by conventional measuring methods or by dye-dilution discharge measurements.

- When selecting the installation site, eliminate any with severe backwater conditions, uneven or broken pipe sections, or excessive potential flow disturbances.

- Always record both depth and velocity output from the Model 250. This will allow detection of velocity probe failures and depth-sensing difficulties.

Trouble-Shooting Guide for Marsh-McBirney Model 250 Flowmeter and Digital Recorder

Table III.4 is a trouble-shooting guide that was used when problems were experienced with the Marsh-McBirney flowmeter and recorder. It is reproduced here to benefit other users of this equipment.

STREET SURFACE PARTICULATE SAMPLING

Street and parking lot surfaces at the four test sites were sampled to characterize accumulation, rainfall-washoff, and street sweeper removal of street surface pollutant loads. Sampling started in May of 1980 at State Fair, Congress, and Hastings, and in July of 1980 at Rustler. Sampling continued through the end of June 1982. The sampling was not conducted during the winter months.

The street cleaning was conducted by a commercial street cleaning firm in Milwaukee, with the following schedules:

Land Use	Baseline Frequency	Accelerated
Commercial Strip	Weekly	2 or 3/Week
Medium Density Residential	Monthly	1 or 2/Week
High Density Residential	Monthly	1 or 2/Week
Parking Lots	Bi-Monthly	Weekly or Bi-Weekly

TABLE III.4
TROUBLE-SHOOTING GUIDE FOR FLOW METER AND RECORDER

FUNCTION	PROBABLE CAUSE	CORRECTIVE PROCEDURE
DIGITAL FLOW RECORDER		
Recorder does not punch	1.0 No voltage going to recorder	1.0 Check fuse at back of precipitation activator or use VOM to check for 12 VDC at terminal barrier strip on timing clock.
	1.1 System 7 failure	1.1 Disconnect Cannon plug from System 7 and attach to recorder. Use test button on recorder to activate motor. Replace System 7 if recorder works.
	1.2 Recorder motor burned out	1.2 Replace recorder
Recorder jammed - tape will not advance	2.0 Usually a stuck pin in punch block	2.0 Replace punch block or recorder
Recorder not registering a dial reading between 4 mA 4000 and 5000 reading	3.0 System 7 locking screw on drive gear or locknut on 10 turn limiter has slipped	3.0 Remove System 7 cover and tighten screw or locknut. Recalibrate recorder for input equal 4000 dial and 19.99 mA input equal 5000 dial reading
	3.1 Flow meter failure	3.1 Check as listed under flow meter trouble shooting
Recorder not responding to changes in discharge, level, or velocity	4.0 Bridge board IS-102 has popped loose from circuit board at back of System 7	4.0 Reattach bridge board
	4.1 Plug-in jack from flow meter disconnected	4.1 Reconnect jack
	4.2 Flow meter failure	4.2 Attach amp meter to plug-in jack from flow meter. If reading less than 3.8, replace flow meter.

TABLE III.4 (continued)

FUNCTION	PROBABLE CAUSE	CORRECTIVE PROCEDURE
	4.3 Power to flow meter off	4.3 Check for blown fuse in flow meter switch panel
MARSH MCBIRNEY MODEL 250 FLOW METER		
Flow increase registered on flow meter chart, but no increase on digital recorder tape - Recorder on time and punching normally	1.0 Plug from flow meter to System 7 disconnected	1.0 Reconnect plug
	1.1 System 7 failure	1.1 See trouble shooting guide for System 7
	1.2 Malfunctioning customer board #1 in flow meter	1.2 Check using amp meter for a 4.0-19.99 mA signal at the plug-in jack for the System 7. (+) at tip (-) on sleeve of jack. If 0.0 mA detected flow meter must be replaced.
	1.3 Malfunction in flow meter	1.3 Check flow meter internal electrical components using the following procedure: Turn off flow meter, insert Calibrate module (yellow 1" diameter plug found inside on cabinet bottom) in place of pipe diameter module, set function switch to CAL and scale switch to 2 mgd, set toggle switch (on right side inside cabinet near velocity adjust potentiometer) to CAL VET. Switch power on. After 3 minutes flow meter should read 50% ± 2% on circular graph or 12 ± 0.35 mA at plug-in jack or 4500 ± 0200 on digital recorder. The flow totalizer should increase 1 unit each 1-1/2 minutes. If readings outside range, contact the USGS.
No flow increase on either circular graph or digital recorder tape	2.0 Flow meter malfunction	2.0 Check operating circuits of flow meter by above 1.3 procedure. If readings normal, continue down following list.

TABLE III.4 (continued)

FUNCTION	PROBABLE CAUSE	CORRECTIVE PROCEDURE
	2.1 Depth sensor malfunction	2.11 Use pressure gage and check for 3.0-4.5 psi air pressure at top part of dessicant chamber. If less, check for disconnected air line between pump & chamber or loose cap on dessicant tube. Finally check for 3.0-4.5 psi at outlet tube on base of flow meter cabinet. If less air, pump must be rebuilt-contact USGS.
		2.12 Check for air bubbles at sensor head in storm sewer. If not evident the dual air line is probably blocked by water or pinched someplace. Contact USGS.
		2.13 If air bubbles exist at sensor head have one person block the air discharge tube or dam water so a depth of 4-6 inches is obtained. A 2nd person switches the flow meter to level and should observe that the low level indicator light will go out and the recorder pen will move up scale. If no increase in level recording occurs, the flow meter should be replaced.
	2.2 Velocity sensor malfunction	2.2 Switch flow meter to Velocity function and observe reading on chart. With water flowing over sensing head, there should be a detectable reading above 0%. If no velocity reading occurs, examine the sensing head in the storm sewer for abrasion to the rear (upstream) electromagnet. It should be flush with the exterior housing. If not, the head must be replaced.
	3.0 Electrical component failure within flowmeter	3.0 This will be identified through 1.3 test procedure above under flowmeter trouble shooting.

The control site in each pair was always swept at the frequency normally maintained by the respective municipalities. Sweeping frequencies at the test sites alternated between periods of normal cleaning frequencies (control periods) and accelerated frequencies (test periods). Street dirt samples were only obtained from the test sites; the control sites were not sampled.

The samples were collected by DNR field staff in Milwaukee, processed at the USGS Hydrology Lab in Madison, chemically analyzed at the Wisconsin State Lab of Hygiene in Madison or the USGS National Water Quality Lab at Doraville, Georgia, and finally summarized and tracked at the DNR Central Office back in Madison.

Experimental Design

Twenty-five street surface subsamples were initially collected using procedures described by Pitt (1979), and weighed individually at each test site in order to determine street loading variability for the sampling design effort. The mean weight and standard deviation of the 25 subsamples were calculated and entered into the formula:

$$N = \frac{4.25\ (S-1)^2}{(r\bar{y})^2}$$

where, $\bar{y}$ = average (mean)
s = standard deviation
r = allowable error
N = number of subsamples required

The allowable error (r) used was 0.25 (alpha = 0.05), resulting in yielding $\pm$ 25 percent errors on estimates of total solids loadings. Lower error terms were not feasible due to the increased subsampling effort that would have been required. To achieve 25 percent error values, from 22 to 32 subsamples were required at each test site (Table III.5). To achieve $\pm$ 20 percent error values, 56 percent more subsamples at each site would have been required.

The Rustler parking lot consists of two distinctly different portions. The eastern half has very smooth asphalt, and the western half has very coarse and cracked asphalt. The two halves therefore had distinctly different loading characteristics. To minimize the total number of subsamples required and to better characterize the loads on the parking lots, these two halves were sampled separately. They are referred to as "Rustler Smooth" and "Rustler Rough" respectively.

State Fair was also found to vary: the residential side streets are not typical of the main commercial strip (Greenfield Avenue). Accordingly, beginning in June of 1981, primary subsampling was done on Greenfield Avenue exclusively, and less frequent subsampling was done on the side streets.

TABLE III.5
NUMBER OF STREET SURFACE SUBSAMPLES REQUIRED FOR + 25%
CONFIDENCE LIMITS ON TOTAL SOLIDS LOADING ESTIMATES

Station	Date of Subsample Test	Number of Subsamples Required
Hastings	June 2, 1980	27
Congress	June 20, 1980	24
State Fair	May 16, 1980	26
Rustler Rough	May 9, 1980	32
Rustler Smooth	June 12, 1980	30
Greenfield Avenue	May 21, 1981	22
Side Streets	May 21, 1981	66*

*Sampling time and car parking problems resulted in 26 subsamples per sample used, for ±40% error values for this category.

Sample Designations

There were three sample designations used in the street surface monitoring program: accumulation (A), after-sweeping (S), and wash-off (W). An "accumulation" sample was collected at any time except within 24 hours after sweeping or within 24 hours after a rain event. An "after-sweeping" sample was collected within 24 hours after the watershed was swept, although the time of collection was usually only one to three hours after sweeping. A "wash-off" sample was collected within 24 hours after a rain event, conditional upon an "accumulation" sample being taken within 48 hours prior to the rain.

Street Surface Particulate Sampling Procedures

Street surface particulate monitoring consisted of sampling loose materials from the surfaces of streets or parking lots within the designated test watersheds. The procedure involved taking a predetermined number of subsamples randomly across the street widths or in the parking lots. These combined subsamples made up one sample.

Table III.6 lists the sampling equipment used to collect the street dirt samples. The samples were collected using two MILWAUKEE Model 8925 industrial vacuum cleaners, each rated at 110 cubic feet per minute maximum air flow. They were connected in tandem, with a PVC Y-connector leading to a 25-foot wire-reinforced vacuum hose, wand, and six-inch nozzle. The equipment and sampling procedures used were similar to those developed by Pitt (1979).

TABLE III.6
STREET SURFACE PARTICULATE SAMPLING EQUIPMENT

1 - 1/2 ton capacity van equipped with a heavy duty cooling system. (1980 Ford Econoline).

1 - 4' x 6' trailer with 32" sides and removable rear gate, fitted with a 1-7/8" ball hitch.

1 - 4000 watt capacity electrical generator with a 16 horsepower engine and electric ignition. WINCO model P4BS-3E/A.

1 - 12 volt heavy duty battery to start the generator.

2 - 120 volt, 10 amp vacuum cleaners. 110 ft.^{3}/min. maximum air flow. MILWAUKEE Model 8925. Connected in tandem with a PVC Y-connector leading to a 25 ft. wire-reinforced vacuum hose, vacuum wand, and 6" vacuum nozzle.

2 - Long handled horsehair brushes.

2 - 3" nylon bristle paint brushes.

Daily street surface monitoring was based on the street sweeping schedule. This schedule was pre-planned for the entire monitoring year, but was flexible to accommodate weather and other unforeseen problems. The sweeping personnel were notified as soon as possible of any schedule changes.

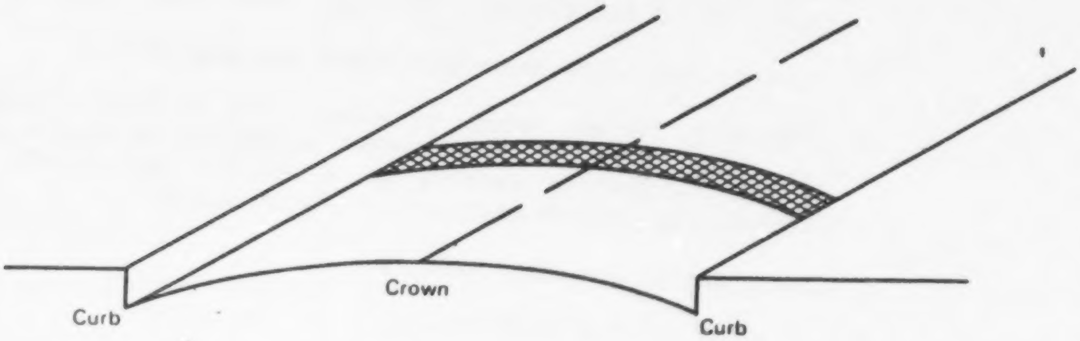
Regardless of sample type (A, S, or W), the first watersheds to be sampled on a daily basis were the areas of high traffic density during the late morning hours. State Fair and Capitol Court - Rustler, both commercial areas, received heavy traffic after 10:00 a.m. each morning and were always sampled before this time. Because of the traffic and the interference of parked cars, these areas were also swept by the street cleaners early in the morning (4-6:00 a.m.). The after-swept samples were therefore always obtained within three to four hours after a watershed was swept. Before cleaning (accumulation samples), however, could be obtained no sooner than 18 hours before sweeping (the morning before sweeping). The residential watersheds (Congress and Hastings) seldom had problems with parked cars or traffic, and could be sampled immediately before and after street sweeping.

The samples were obtained by vacuuming many narrow strips across the streets (as shown in Figure III.5) throughout the study area. The sampling procedure must adequately describe the street dirt loadings so care was taken to use appropriate sampling procedures and to obtain a sufficient number of subsamples.

Each subsample was intended to include at least all of the street surface material that would be removed during a severe rain (including loose materials and caked-on mud in the gutter and street areas). The locations of the subsample strips needed to be selected to ensure that they had no unusual

FIGURE III.5

LOCATION OF SUBSAMPLING STRIPS ACROSS A STREET


Crown
Curb
Curb

loading conditions. For example, a subsample can not be collected through the middle of a pile of leaves. It must be collected where the leaves are lying on the street in their natural distribution pattern. When possible, wet areas also needed to be avoided. Each subsample was collected in a narrow strip about six inches wide (the width of the vacuum sampler intake) from the center of the street to the curb.

When sampling, the leading edge of the gulper needed to be slightly elevated above the street surface (1/8 inch) to permit pebbles and large particles to enter. The gulper is lifted more to accept larger material as necessary. A large accumulation of leaves in the subsample strip needed to be manually picked up and placed in the sample storage container in order to prevent the hose from clogging.

An important aspect of sample collection was the speed at which the gulper is moved across the street. A very rapid movement significantly decreases the amount of material collected, while too slow a movement requires more time than is necessary. The correct movement rate depended on the roughness of the street and the amount of street dirt. When sampling a street having a heavy loading of particulates or a rough surface, the wand should travel at a velocity of less than one foot per second. In areas of lower loadings and smoother streets, the wand can travel at a velocity of two or three feet per second. The best indication of the correct collection speed was made by a visual determination of how well the street was being cleaned in the sampling strip and by listening to the collected samples rattling up the wand and through the vacuum hose. The objective is to remove at least everything that is lying on the street that could be removed by a significant rainstorm. It was quite common to leave a visually cleaner strip on the street where the subsample was collected, even on streets that appeared to be clean.

Occasionally, unusual conditions on the street surface called for specialized sampling techniques. Frequently, fine clay-like soil tightly adhered to the street surface. This material was loosened and included in the sample by scraping the area with a shoe and vacuuming. Leaves along the curb (also within a subsample strip) were manually collected with a six inch flat stainless steel scoop and placed in the sample container. Wet areas were avoided as the moisture caused clumping and adherence of the sample to the vacuum canister.

Several hundred grams of sample material were needed for the laboratory tests. Each after street-cleaning subsample was not collected from exactly the same location as the before-cleaning subsample. They were taken from the same general area, but at least a few feet apart.

Sample Transfer

After all the subsamples for a test area were collected, the hoses and wand were cleaned. Leaves and rocks that may have become caught were carefully removed and placed in the vacuum can or sample container. The generator was then turned off and the vacuum was then emptied at the last station or at a more convenient location.

To empty the vacuum, the top motor unit was removed and placed out of the way of traffic. The secondary, coarse vacuum filter was then removed from the vacuum can, and using a small whisk broom, was carefully brushed into the vacuum canister. The primary dacron filter bag was kept in the vacuum can and shaken carefully to knock off most of the filtered material. (The hose inlet was blocked with a leg or knee and the primary filter bag was held onto the drum with arms and chest.)

The dust inside the can was allowed to settle for a few moments, then the primary filter was removed and brushed carefully into the sample container with the brush. Any dirt from the top part of the bag where the bag was bent over the top of the vacuum was also carefully removed and brushed into the canister.

The inside of the vacuum can was brushed out through a drain hole in the bottom of the canister. In order to prevent excessive dust losses, the emptying and brushing was done in areas protected from the wind. To prevent inhaling the toxic sample dust, safety glasses and dust filters were worn while removing the samples from the vacuum.

The sample storage containers were labeled with the date, the test area's name, and an indication of whether the sample was taken before or after street cleaning or if it was an accumulation (or other type of) sample. Finally, the lids of the sample containers were taped shut and transported to the laboratory for analyses.

Street Surface Particulate Sample Processing

Most street surface samples are quite dry and do not experience chemical or biological degradation over short storage periods for the constituents typically monitored. Exceptions include bacteria, mercury and some phosphorus forms which require immediate sample analysis. In Milwaukee, street surface particulates can lie exposed on the road surface for several days before rains wash them into the receiving waters. During this time, they may be intermittently moistened and subjected to a wide range of temperatures. Although the laboratory storage times should be kept to a minimum, they are likely to be several months long due to the necessity of compositing samples over testing time periods, as described in this section. After sample collection, the samples were sent to the USGS Hydrology Lab in Madison for processing. There the samples were split into nine particle sizes, by sample type and sampling period, and forwarded to either the Wisconsin State Lab of Hygiene in Madison or the USGS National Water Quality Lab in Doraville, Georgia for chemical analysis. The particle size fractions are as follows (mm): less than 0.031, 0.031-0.063, 0.063-0.125, 0.125-0.25, 0.25-0.50, 0.50-1.0, 1.0-2.0, 2.0-4.0, and greater than 4.0 plus grass and leaves fractions.

Before the physical analyses, the samples were transferred from their storage containers to labeled drying pans. These pans were then placed in a low temperature drying oven for several hours at 70-75 degrees F. Again, this heating does not typically affect the chemical characteristics of the samples, except for bacteria and the more volatile phosphorus and mercury compounds that may be analyzed in street surface particulates. If significant amounts of constituents of importance are lost during sample drying, then subsampling of the complete sample mixture for analysis for those specific compounds may be necessary. However, because of the heterogeneity of the street surface particulates, obtaining a representative subsample from the whole sample is extremely difficult and can introduce significant errors. The gross and net weights of the samples were noted and the percent moisture was calculated. Again, this complete information was noted for each sample in order to resolve problems that may later occur due to misplacing or mislabeling samples.

The procedure used to separate the sample into the nine size fractions, plus grass, and leaves and twigs was as follows:

- Transfer all information from the label on the sample container to the sample log sheet: station name, date, type of sample, number of subsamples, time, sample number, and any miscellaneous information.

- Record the net weight of the sample to the nearest 0.1 gram on the log sheet.

- Transfer the weighed sample to a 4.0 mm sieve set atop a 0.125 mm sieve and pan. Remove by hand any large pieces of grass, leaves, and twigs. Deposit the vegetative material in a separate container. Briefly shake the sieves and, if any vegetative material remains, carefully transfer a workable amount from the 4.0 mm sieve into a flat-bottomed stainless steel pan (12" x 20" x 4") which should be resting at a 20° angle.

- Separate the vegetative material from the dust and dirt by alternately combing the vegetative material to the upper end of the pan using the coarsest comb and tapping the pan bottom to settle the dust and dirt to the lower end. Remove and deposit the vegetative material in labeled containers. Most of the vegetative material can be removed by repeating the procedure using two additional combs with successively smaller tine separations. After all the vegetative material from the 4.0 mm sieve has been removed, process the material in the 0.125 mm sieve in the same manner. Combine the residual "nonvegetative" material with the material in the pan. If the sample is more than 300 grams, split the sample into workable fractions using a stainless steel particle-size splitter (i.e., Tyler SS50 and SS100). Weight the fractions to the nearest 0.1 gram.

  The combs used had the following specifications:

Type	Manufacturer	Overall Width	Tine Spacing
Coarse	Locally fabricated	158 mm	7.5 mm
Medium	PSI-800C Pet Comb	145 mm	3.0 mm
Fine	PSI-800M Pet Comb	145 mm	1.0 mm

- Pour the fraction to be split into the nest of Tyler stainless steel sieves (2.0, 1.0, 0.5, 0.25, 0.063 mm and pan) and run in the Rotap for 15 minutes.

- Empty and weigh the contents of each sieve to the nearest 0.1 gram. Record the weights on the sample log sheet.

- Weigh the contents of the pan and, if greater than 15 grams, split the sample and process in the FAHCO Particle Classifier to separate the particles smaller than 0.031 mm. Weigh the sample fractions on an analytical balance and record the weight on the sample log sheet to the nearest 0.01 gram.

- Complete the sample log sheets by computing the total weights for each particle size where a sample split had to be made.

- Package and label the different particle sizes in separate containers.

Chemical Analyses of Street Surface Particulate Samples

The samples were composited by particle size, test site, study period, and type of sample. Equal quantities of street dirt for each particle size, representing the same study area and short time period (six to seven weeks), were combined for chemical analyses. As an example, 12 street dirt samples may have been obtained from a two month period at one of the sites. Each of these twelve individual samples were separated into the different particle sizes. Equal quantities of separated samples were then taken from each sample and combined. This two month period for this study area was therefore represented by a composite sample for each particle size. The chemical characteristic results were then applied to each of the twelve individual samples (by particle size). The composited samples for the 2.0, 1.0, and 0.5 mm particle sizes were sent to the USGS National Water Quality Lab at Doraville, Georgia. These samples are pulverized and analyzed for total phosphorus, total lead, volatile solids, and COD. The remaining samples from 0.25 mm to less than 0.31 mm were sent to the Wisconsin Stabe Lab of Hygiene and were analyzed for the same four constituents. The fractions greater than 4.0 mm were not chemically analyzed because of the extreme variabilities found in these samples (i.e., cigarette butts, glass, paper, rocks, etc.).

Equal sample quantities were composited because the objective was to obtain a time averaged chemical description of the material. The time phases for compositing were based upon major seasonal differences and street cleaning practices conducted within each area. It is much more important to analyze different particle sizes for the different chemical constituents than analyzing each separate sample. The chemical concentrations vary substantially between different particle sizes. This variation is known to be much greater than either seasonal or aerial variations. In addition, it is very difficult to subsample a complete sample to obtain a representative five or ten gram subsample. The extreme heterogeneity of the samples makes this difficult without milling all of the sample and then removing the small quantity necessary for chemical analysis. It is much easier to select a representative five or ten grams from each particle size because of the reduced physical and chemical variation within that size range. Each composited sample was typically made up of five to 20 subsamples. These composited samples were then placed in small sample containers that were labeled and sent to the laboratory for chemical analysis.

STREET TEXTURE SAMPLING

The accumulation of street particulate pollutants is mostly affected by street surface texture (Pitt, 1979). Street sweeper effectiveness, stormwater runoff removal, and accumulation rates are better understood if a quantitative measurement of texture is possible. Wind speed and direction, traffic speed, and dirt density are also important factors that must be considered (Pitt, 1979). The condition of the street surface (cracks and depressions) is often as important as texture, although the two are not separated in this survey.

Experimental Design

Street texture measurements were randomly obtained over selected texture categories within the test watersheds of the Milwaukee NURP study. These categories were chosen by visually estimating the textures of the streets in each watershed. These categories were then marked on aerial photographs, along with a grid using house numbers as potential measurement sites.

The four test watersheds (W. Congress, State Fair, Hastings, and Rustler) were divided into eleven categories according to visual interpretation: five in State Fair, three in W. Congress, two in Rustler, and one in Hastings. Individual texture measurements for each category numbered from six to 30. The number of measurements within a category was chosen by several factors; time availability, desired error, and parking and traffic conditions.

Collection of Street Surface Texture Data

Street surface texture measurements have been made by several procedures, some of which are very elaborate and were beyond the scope of this study. Most of these methods have been developed primarily for measurement of skid resistance of tires on pavement (Henry and Hegmon, 1975; Doty, 1975).

For the purposes of this study, the most convenient sampling method was to utilize a device known as an outflow meter. This device was first developed for measuring road drainage capability by Kummer of Pennsylvania State University. It consists of a clear plastic tube with a weighted metal base and a neoprene gasket, glued to the base to act as a seal.

The outflow meter used in this study consisted of an 18 inch long plastic tube with lines marked at 3 and 15 inches (12 inches apart). The base is an aluminum ring with an outer diameter (O.D.) of 5-3/4 inches and an inner diameter (I.D.) of 3-1/4 inches. A reopen gasket is glued to the bottom of the base and has an O.D. of 4-1/4 inches and an I.D. of 3-1/4 inches. A 15 pound ring-shaped weight was attached on the base to compress the rubber gasket.

Relating street texture was determined by timing the rate at which water flowed out of the plastic tube (between the two reference lines) and through the small gaps between the street surface and the rubber gasket. The street surface texture of the "test" watersheds varied widely, according to the results of the outflow tests. Outflow times from less than two seconds, representing a cracked or pitted surface to more than 305 seconds, for smooth and traffic-flattened asphalt, were recorded. Asphalt, concrete, and oil and screens street surface types were measured, all in various states of repair.

Categories within each watershed were chosen prior to texture measurements by visual estimation and by considering the results of the street sampling experimental design tests. The outflow results indicated a high variability within these categories (occasionally, more than between categories). This high variability within the categories may have been caused by cracked pavement.

The data trend indicated that asphalt surfaces are generally smoother than concrete surfaces of the same age. The most heavily used sections of a street are the traffic lanes and it was suspected that these regions provided the major difference in these two pavement types.

Asphalt streets have traffic lanes which are very smooth and flat, whereas concrete traffic lanes become rough and pitted. All of the longer outflow times (60-306 secs.) were from the traffic lanes of asphalt streets. The inverse seems to be true for very new pavement. Newly placed asphalt is usually rougher in texture than concrete, although some concrete is formed with very shallow grooves, to provide better traction and water drainage. Both pavement types develop flaws as they age. Asphalt tends to crack and split while concrete develops pits and becomes rough in general.

A one-way analysis of variance test (ANOVA) was applied to the data from the eleven texture categories of all four watersheds to determine if the categories and sites were significantly different. The analysis indicated that the categories were significantly different (F-ratio = 4.73; hypothesis: texture strata 1 to 11 are equal; can be rejected with 99.9% confidence). For further clarification, data were randomly selected from the original eleven texture categories to yield a representative number of data for the street lengths of each sub-area. These data were then pooled to form four individual categories corresponding to the four test watersheds. A one-way analysis of variance was again performed on this watershed data to determine if the street textures were significantly different between each watershed. The test verified that the four watersheds had significantly different street textures (F-ratio = 2.81; hypothesis: all four watersheds had equal textures; can be rejected with 95% confidence).

Based on the mean outflow times for the randomly selected data, the watersheds can be ranked from roughest to smoothest as follows:

. Congress	15.1 secs.
. Rustler	23.6 secs.
. Hastings	24.1 secs.
. State Fair	38.9 secs.

The State Fair watershed had a large relative standard deviation of "texture" (68.9 secs./38.9 secs. = 1.77). This data variability was due to the diversity of street surface conditions and pavement types throughout the watershed. When median outflow times are considered (instead of average values) State Fair ranks as the roughest area rather than the smoothest area, indicating lower rather than higher outflow times. This difference is due to the data variations noted above. The higher outflow times were all recorded on Greenfield Avenue and S. 76th Street (both asphalt).

Weighted means of the outflow data for the four watersheds were determined as a more appropriate measure:

$$\frac{(X_1 \,.\, L_1) + (X_2 \,.\, L_2) + \ . \ . \ . + (X_n \,.\, L_n)}{L1 + L2 + \ . \ . \ . + Ln}$$

where,
X_n = mean outflow time for street section n
L_n = length of street section n

The weighted means and ranking order (from roughest to smoothest) were:

.	Congress	15.7 secs.
.	Rustler	23.6 secs.
.	Hastings	24.1 secs.
.	State Fair	36.2 secs.

The ranking order was identical to the order of the means from the randomly picked data. The weighted mean values were also nearly identical to the mean values from the randomly picked data.

The Rustler-rough and Rustler-smooth mean outflow times were 16.5 and 30.6 secs. respectively. This large difference confirms that they had differed textures and justifies their separation in the vacuum-sampling procedure. The State Fair watershed was also separated into two areas for vacuum-sampling, "Side Streets" and Greenfield Avenue. These areas were also substantially different in their weighted mean outflow times. The results indicate that the side streets (29.8 secs.) were much rougher than Greenfield Avenue (56.6 secs.)

From the statistical analysis of the data, it appears that the four watersheds can be ranked in terms of general street surface texture. Rustler and Hastings were very similar in overall texture and may not be statistically different. Rustler has two distinct texture areas within it and interpretation of the watershed, as a whole, should not be made. Hastings is the most uniform of all four watersheds, having a mean of 24.1 secs. and a standard devialation of only 8.8 secs. (for a relative standard deviation of only 0.37). The streets of the Hastings watershed were all constructed at roughly the same time and are made of concrete, still in excellent condition. The streets of the Congress and State Fair watersheds were composed of both asphalt and concrete, all of differing ages. The State Fair watershed, in particular, was quite variable in street surface type and condition. The data reflect this by a high relative standard deviation.

In general, the data obtained from the outflow meter accurately describes the perceived visual impression of the watershed. It is concluded that this method can be used to accurately determine street surface textures.

Outflow Meter Precision

The precision of the street surface texture measurement device (outflow meter) was tested in a series of replicates on two textures. The areas tested were 77th Street in the State Fair watershed and the "Rough" area section of the Rustler parking lot. 77th Street was characterized as a medium-textured asphalt street, and Rustler's "Rough" as a coarse, pitted asphalt surface. There were 20 replicates taken at each location, all with the outflow meter at the same exact position. Sampling methods were identical to those described earlier. Outflow rates were timed with a stopwatch.

The standard deviations of the two sample sets were nearly identical, despite having different means. The mean at 77th Street was 18.27 secs. with a standard deviation of 0.35 secs., while Rustler Rough had mean and standard deviation values of 12.78 and 0.34 secs. respectively. The relative standard deviation values were about 0.02. The 95% confidence intervals were 18.10-18.44 secs. at 77th Street, and 12.62-12.94 secs. at Rustler Rough. These results indicate acceptable precision of the outflow meter measurements, allowing transferable use of the texture data.

ATMOSPHERIC WET AND DRY DEPOSITION SAMPLING

The transport and deposition of atmospheric pollutants has become an increasingly studied phenomena. Long and short range transport of natural and anthropogenic material presents a potential threat to the quality of life in urban and rural areas alike. Atmospheric sources of lead, phosphorus, nitrogen, metals, and PCB's have been determined to constitute a significant portion of their total loadings to the Great Lakes (Andren and Stolzenburg, 1979; Doskey, Andren and Strand, 1979; and Kuntz, 1980). Particulates (20 microns) are being introduced to the earth's atmosphere at an estimated rate of 240 to 750 million metric tons per year as a result of man-made activities. Emissions from combustion processes have been found to result in local and long range transport of NO_x and SO_x, precursors to acid rain (Brosset, 1978; EPA, 1980; GLSAB, 1979, and Pinkerton, 1981). Studies have also documented the destructive effects of wet and dry deposition on surface waters, aquatic biota, and materials composition of urban structures (Hutchinson, 1981; Pfeiffer and Festa, 1980; and Shriner, 1980). Pollutant deposition, both wet and dry, upon urban, impervious surfaces is especially critical due to the availability of these pollutants for direct transportation to water resources (Barkdall, et. al., 1977; Novotny, et. al., 1979).

The atmospheric deposition network was installed with the objective of identifying wet/dry atmospheric pollutant loadings to urban watersheds in the metro-Milwaukee area. There were eight collector sites representing residential, industrial, and commercial land uses, or mixes of these uses. Four sites were shared with hi-volume particle samplers maintained by the Wisconsin Department of Natural Resources Air Monitoring Section. The Hi-Vols collect particles less than 100 microns in diameter (range; 0.1 to 100 microns) for determining the mass concentration of suspended particulates in ambient air.

Atmospheric Deposition Site Selection and Description

The project objectives for wet/dry deposition monitoring required that the monitoring sites be close to, or within, the study areas (Figure III.6). Two collectors were located within or near each study watershed. Two collectors better identify the variability between collectors and within the area of interest. Galloway and Likens (1978) concluded that variability in precipitation data is in part generated by sampling errors and choice of collector location. The criteria for collector locations in the NURP study was based on criteria developed for hi-volume air quality monitoring units as shown on

FIGURE III.6

ATMOSPHERIC DEPOSITION MONITORING SITE LOCATIONS

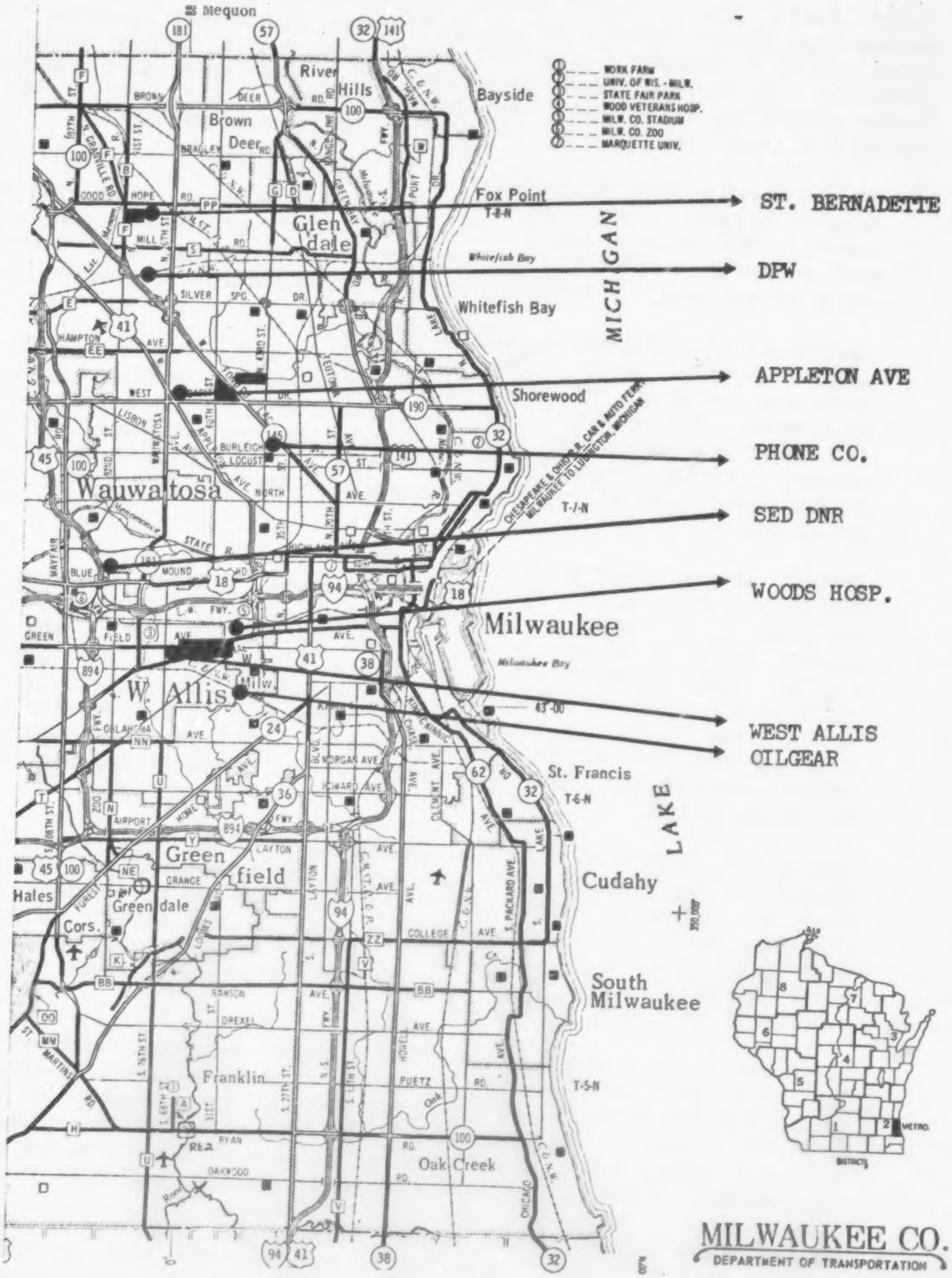

ST. BERNADETTE
DPW
APPLETON AVE
PHONE CO.
SED DNR
WOODS HOSP.
WEST ALLIS
OILGEAR
① WORK FARM
② UNIV. OF WIS. - MILW.
③ STATE FAIR PARK
④ WOOD VETERANS HOSP.
⑤ MILW. CO. STADIUM
⑥ MILW. CO. ZOO
⑦ MARQUETTE UNIV.
Mequon
River Hills
Bayside
Brown Deer
Fox Point
Glendale
Whitefish Bay
Shorewood
Wauwatosa
Milwaukee
W. Allis
St. Francis
Cudahy
South Milwaukee
Greenfield
Greendale
Hales Cors.
Franklin
Oak Creek
LAKE MICHIGAN
MILWAUKEE CO.
DEPARTMENT OF TRANSPORTATION

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Table III.7. The collector height was variable; at or greater than two meters from ground level. Height differences can affect observed loading rates due to a tendency for ground based collectors to obtain larger sized particles (reflecting local characteristics) than collectors located at higher elevations (reflecting long range transport) (USGS, 1980). The following list describes the wet/dry deposition monitoring stations:

- St. Bernadette (8202 W. Denver)
  Sampler height: 5.8m. The sampler was located on the roof of a middle school, 200 meters north of the Burbank watershed. Land-use is medium-density residential. There is a large grassy field immediately north of the site. The roofing surface is composed of tar and pea gravel.

- Department of Public Works (8400 W. Florist)
  Sampler height: 7.9m. The sampler was located on the roof of a two-story building, 800 meters south of both the Burbank and Hastings watersheds. The building is within 300-400 meters south of several small industrial operations and within 15 meters of two relatively low-traffic streets. A high school is to the southeast and a medium-density residential area is to the south and southwest. The roof was made of tar and pea gravel.

- Appleton Avenue (7528 W. Appleton Ave.)
  Sampler height: 8.2m. The sampler was on the roof of a leased office building in a commercial-residential area. Appleton Avenue, a heavy traffic area, is within 20 meters west of the sampler. 76th Street, another heavy traffic area, is within 100 meters. The sampler is approximately 1.5 kilometers west of the Capitol Court (Post Office and Rustler) and Lincoln Creek watersheds. The roof surface is tar and pea gravel. This site was used in conjunction with high-volume particulate, carbon monoxide and ozone monitoring by the Southeast District DNR air monitoring staff.

- Wisconsin Telephone Co. (3281 N. 41st Street)
  Sampler height: 17.4m. The sampler was on a three-story, tar papered roof, 1.5 kilometer southeast of the Capitol Court watershed and 1.2 kilometer south of Congress. The land-use is high-density residential. Fond du Lac Ave. is a heavy traffic area and is within 200 meters to the north and east of the sampler. There was also a hi-volume particulate sampler at this site.

- Southeast District Headquarters (DNR) (9722 W. Watertown Plank Road)
  Sampler height: 2m. The sampler was on a ground platform 30 meters west of the DNR lab building and 130 meters east of State Highway 45 (extremely heavy traffic). The immediately adjacent area is all open, grassy Milwaukee County land. There is a wooded area 15 meters to the north of the sampler. There is also a hi-volume particulate sampler at this site.

- Wood Veterans Hospital (Wood, WI)
  Sampler height: 13.4m. The sampler was on the roof of a research laboratory building and was 300 meters east of the Wood Center watershed. National Avenue, which receives heavy traffic, borders the hospital grounds and is roughly 100 meters south of the sampler site.

TABLE III.7
TOTAL SUSPENDED PARTICULATE MONITOR SITING CRITERIA*

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1. Air intake must be 2 to 15 meters above ground level.
2. For roof locations, the sampler must have greater than two meters separation from walls, parapets, penthouses, etc.
3. No furnace or incineration flues should be nearby.
4. Sampler should be greater than 20 meters from trees.
5. Distance from sampler to obstacles must be at least twice the height the obstacle protrudes above sampler.
6. Must have unrestricted airflow in an arc of 270° around sampler.
7. Should have greater than 25 meters of separation from roadway which is elevated greater than five meters above ground.
8. Sampler should be in a paved area or area which has vegetative ground cover year-round.

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*per Federal Register, Vol. 44, No. 92. Thursday, May 10, 1979.
p. 27592-27596

The area is heavily industrialized to the east with some commercial land-use to the south and southwest. High density residential areas border to the south and west. The roof surface is composed of tar and pea gravel.

- West Allis City Hall (7525 W. Greenfield Ave.)
  Sampler height: 10.8m. The sampler was on a third-story, tar and pea gravel roof, immediately within the State Fair watershed. Two heavy traffic areas are within 30 meters of the building: Greenfield Avenue to the north, and 76th Street to the west. The land-use is residential to the near south and west, and commercial to the north and east. There is also a significant amount of industry in the general area.

- Oil Gear Corporation (2300 S. 51st Street)
  Sampler height: 2m. The sampler was on a ground platform in a large grassy field, 75 meters east-southeast of the factory. There are no significant streets in close proximity to this site. The surrounding land-use is industrialized to the north, east and near west. Residential land-uses are to the west and south. The Wood Center watershed is about 2.5 kilometers to the northwest. There was also a hi-volume particulate sampler at this site.

Atmospheric Deposition Sample Collection

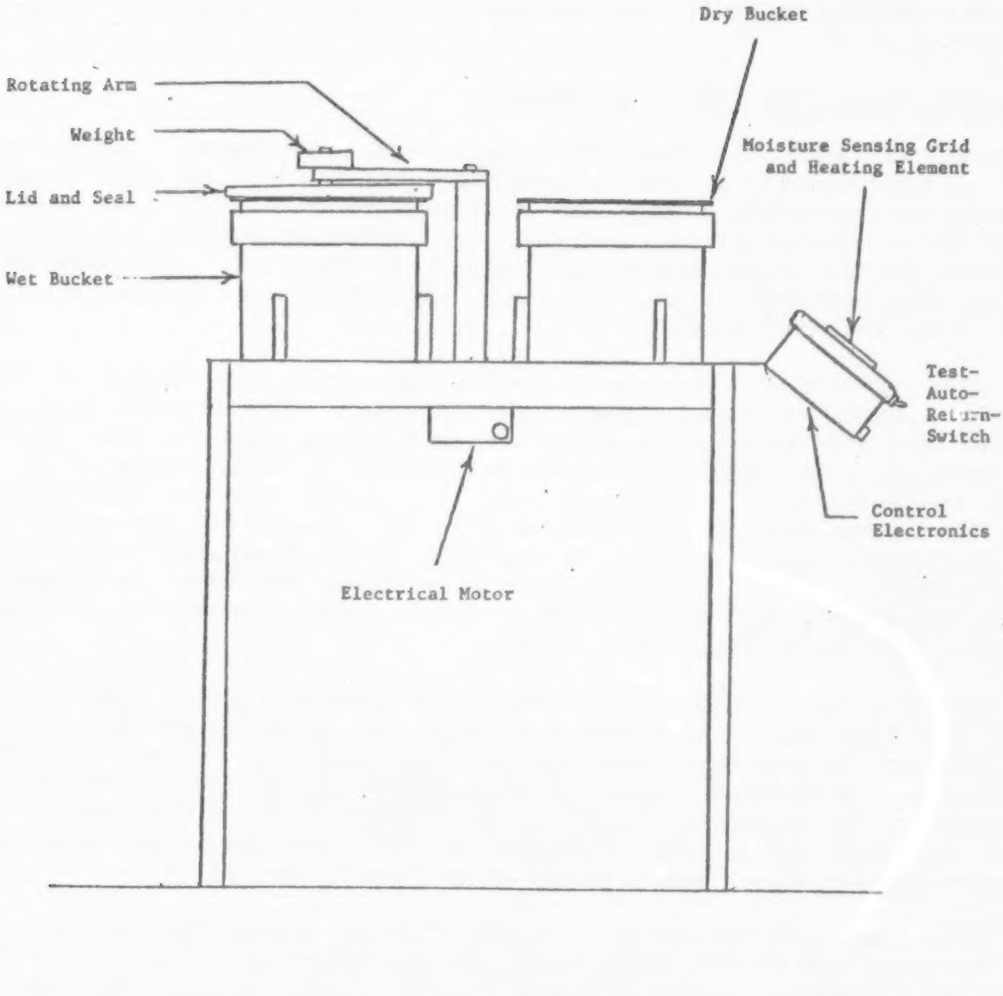
All samples were collected with wet/dry deposition collectors manufactured by N-CON of New York (Figure III.7). The collectors segregate dry and wet deposition by utilizing a lid transfer mechanism and two collection buckets. Rain or snow activates the lid transfer mechanism so the dry collection bucket is closed and the wet collection bucket is open during precipitation events. The lid reverses when rain or snow stops and dry deposition monitoring continues.

The N-CON collectors' precision and accuracy for the collection of gravity settled particles (greater than two microns in diameter), aerosols (less than two microns) and absorbed gases is unknown. It is suspected that bucket collection is biased towards large particles (Pinkerton, 1981).

This type of sampler was used in similar wet/dry atmospheric deposition monitoring networks located in the U.S and Canada (Pinkerton, 1981). The wet/dry sampling devices appear similar (with respect to auto-sensing capabilities and bucket type collection, despite the varied designs) to samples from several other manufacturers (N-CON, Aerochem Metrics, Sangamo). At least two projects, the National Atmospheric Deposition Project and the Great Lakes Precipitation Quality Monitoring Network, utilize plastic bag inserts for all wet collections. This eliminates the bucket cleaning procedure used by this NURP project for wet collection buckets. Dry deposition collection may be better conducted with a rigid uniform bucket, where the exposed surface area is constant. Because dry deposition rates are partly a function of collector surface properties (Pinkerton, 1981), dry deposition loading comparisons between networks utilizing various dry collection devices should include a materials description of dry collector composition.

FIGURE III.7

N-CON ATMOSPHERIC DEPOSITION SAMPLER


Dry Bucket
Rotating Arm
Weight
Moisture Sensing Grid and Heating Element
Lid and Seal
Wet Bucket
Test-Auto-Return-Switch
Control Electronics
Electrical Motor

Both the wet and dry buckets are manufactured by Vulcan Plastics in Illinois and are made of high density polyethylene, 90 mils thick, with a bucket opening diameter of 0.285 meters resulting in a collection area of 0.064 square meters.

Contamination of buckets due to collector design flaws and natural circumstance was suspected early in the project. Quality assurance tests were conducted to investigate these potential sampling problems and are discussed later in this report.

A trouble shooting guide for the atmospheric deposition samplers is shown in Table III.8.

Atmospheric Deposition Sample Processing

Wet deposition (rain and snow) was sampled for every event. Samples were picked up and processed as soon as possible (usually within 24 hours or less) following precipitation. There was no field preservation of wet samples. Appropriate preservatives were added to the samples at the DNR laboratory in Milwaukee shortly after sample collection. Acidity, pH, and conductivity analyses were performed in the laboratory immediately after sample collection on wet (rain and snow) samples.

Wet sample processing consisted of sample inspection and removal of large particles (including leaves, twigs and insects). The buckets were then scrubbed with a polyethylene brush to loosen adhering particles from the bottoms and sides. The samples were then transferred to an Erlenmeyer flask for volume determinations. The samples were then poured into the DECA splitter where the entire volumes were divided into the appropriate laboratory bottles. Sulphuric acid was added to the COD, total phosphorus, and nitrogen series samples. Nitric acid was added to preserve the total lead samples. Soluble phosphorus and soluble lead allquots were obtained by filtration through a 0.45 micron glass fiber filter.

Dry deposition was initially monitored on a monthly basis. Sampling frequency was increased to approximately twice per month in mid-August 1981. Dry deposition samples were inspected for large particles introduced by winds and insects. A standard volume of distilled/deionized water (400 ml) was then added to the bucket for scrubbing and removal of the actual sample. The sample was then split into laboratory bottles and preserved using acid additions similar to wet sample preservation (see Figure III.8).

Much effort was made to design a sample tracking system that would insure that the many samples collected would not get mixed up. Table III.9 discusses this tracking system. Sample log-in sheets showing the sampling periods and analyses conducted were maintained for the wet and dry deposition samples.

Tables III.10 and III.11 are individual sample sheets containing specific collection notes. These tables are an important element of the sampling quality assurance/sample collection task and significantly reduce the chances for losing samples. Table III.12 summarizes the sample preservation requirements and maximum holding times for the atmospheric deposition samples.

TABLE III.8
TROUBLE SHOOTING GUIDE FOR ATMOSPHERIC DEPOSITION SAMPLERS

MALFUNCTION	PROBABLE CAUSE	CORRECTIVE PROCEDURE
Precipitation activator on standby (red light on)	1.0 Less than 0.01 inch precipitation	1.0 Normal condition
	1.1 Greater than 0.01 inch precipitation	1.1 Continue down check list
	1.11 Coax cable not inserted in the precipitation collector	1.11 Test unit by inserting end of cable in 1" of water. Unit should activate (green light on)
	1.12 Power outage	1.12 Test unit to confirm operation
	1.13 Fuse blown in positive 12 VDC wire at back of precip. activator	1.13 Replace fuse
	1.14 Integrated circuit 4011 burned out	1.14 Remove base of precip. activator and replace IC 4011.
Precipitation activator will not switch to standby	2.0 Precipitation collector full of water	2.0 Drain collector and try again
	2.1 End of coax cable damaged so that braided jacket & center conductor shorting out	2.1 Repair cable
	2.2 IC 4011 failure	2.2 Remove base plate of precip. activator and replace IC 4011

FIGURE III.8

ATMOSPHERIC DEPOSITION SAMPLE PROCESSING

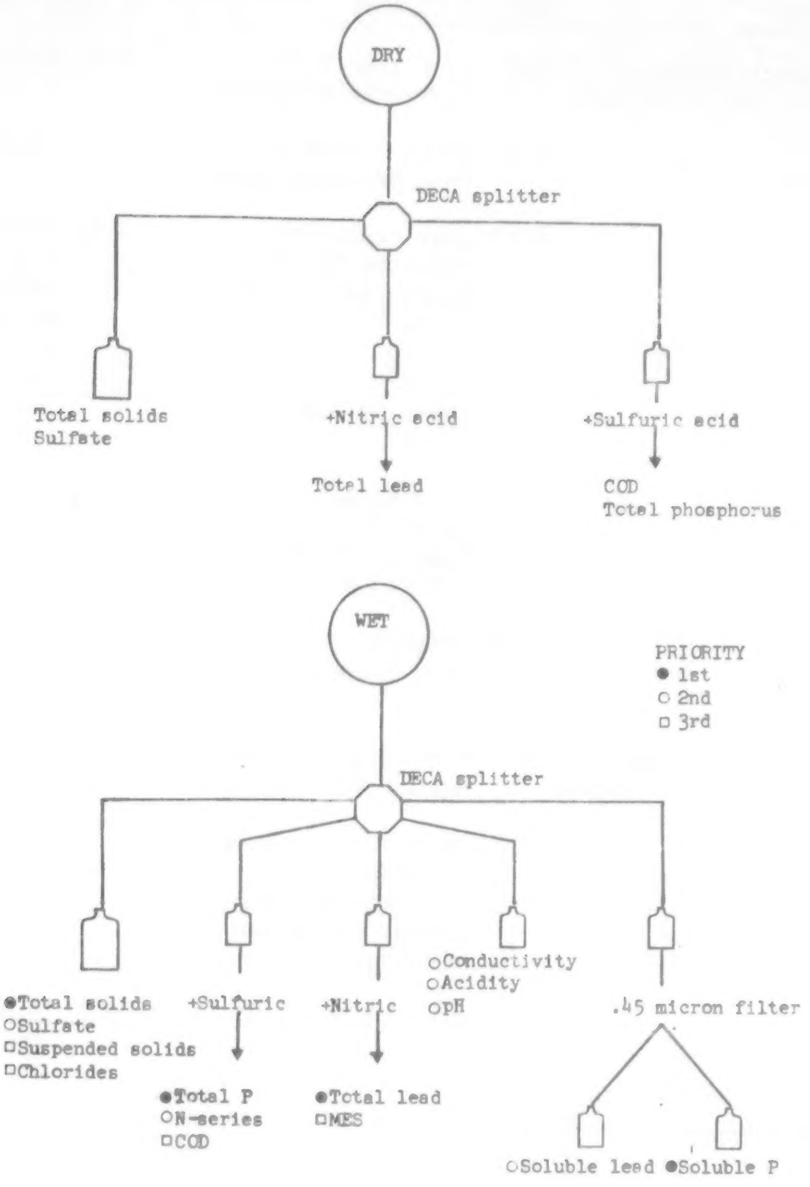

DRY
DECA splitter
Total solids
Sulfate
+Nitric acid
Total lead
+Sulfuric acid
COD
Total phosphorus
WET
PRIORITY
● 1st
○ 2nd
□ 3rd
DECA splitter
●Total solids
○Sulfate
□Suspended solids
□Chlorides
+Sulfuric
●Total P
○N-series
□COD
+Nitric
●Total lead
□MES
○Conductivity
○Acidity
○pH
.45 micron filter
○Soluble lead
●Soluble P

TABLE III.9
ATMOSPHERIC DEPOSITION SAMPLE TRACKING

Bucket label with end date information filled in at time of bucket collection (immediately after rain)

Station DPW #413703
Begin Date 5/11/81 Time 1030
End Date 5/11/81 Time 1430
Dry Rain Snow
Comments

Bucket label with start date information filled in at time of initial bucket placement (upon removing previously placed bucket)

Station DPW #413703
Begin Date 5/11/81 Time 1030
End Date Time
Dry Rain Snow
Comments

Use these labels to identify all buckets placed in the N-CON precipitation collectors. They should be placed on the bottom of each bucket. When returning to the lab for sample processing they can be used to identify the transfer container previous to splitting and preserving, etc.

The same type label is used for both wet and dry buckets. Circle the precipitation collected as either DRY, RAIN, or SNOW.

Rain and snow samples will be collected on an event basis while dry samples should be collected every two weeks.

All sample containers should be tightly sealed during transfer to avoid contamination.

Several records are maintained for tracking of collection and placement dates, time, and other information and observations.

1) Bucket Labels - Identify location, time, and type of sample collected.

2) Field Notes - Are maintained for the above information and to record maintenance of N-CON units. Any observations should be recorded which could affect the nature of the samples.

3) Bucket Collection Schedule (on office wall) - This schedule is designed to provide a fast and visible accounting of bucket collection and placement dates.

TABLE III.9 (continued)

4) Atmospheric Deposition Sample Record - This form is filled in during the lab processing of samples (see Figures 1 and 4) and includes pertinent individual sample information.

5) Wet/Dry Sample Log - Used to record parameters analyzed, field #'s, dates, and pH, conductivity and acidity determination.

Bottle Labelling

Use these labels to identify the various chemistry bottles used during the splitting procedure. They are color coded in conjunction with the splitting diagram. Cross off all aalysis that will not be run. The proper field designation should be circled with the event # written in. In this example, R-001 indicates the first rain sample collected at DPW. D-001 would indicate the first dry sample collected at DPW. S-001 indicates the first snow sample. The field # is also indicated on the "wet/dry sample log" form (filled in during processing).

(Green)

Station DPW Dates
Storet # 413703 5/15
Field S,R,D# 001
Analysis:
Tot. Pb, Sol. P, MES

(Yellow)

Station DPW Dates
Storet # 413703 5/15
Field S,R,D# 001
Analysis:
Tot. P, COD, NO_2-NO_3, NH_4,
Tot. Org. N.

(Red)

Station DPW Dates
Storet # 413703 5/15
Field S,R,D# 001
Analysis:
Tot. Sol. SO_4, SS, Cl,
Sol. Lead

TABLE III.10
WET ATMOSPHERIC DEPOSITION SAMPLE RECORD

DATE: From ______________ @ ______________ to ______________ @ ______________

STATION NAME: ______________________________

STATION NUMBER: ______________________ SAMPLE NUMBER: ______________

TYPE OF PRECIPITATION: RAIN __________ SNOW __________

DATE OF APPROX. TIME OF RAIN/SNOW: ______________________________

VOLUME OF SAMPLE: ______________________________

COMMENTS (Floating material, insects, etc.):

IS THE SAMPLER FUNCTIONING CORRECTLY? YES _____ NO _____

IF NOT, WHY?

ACIDITY to pH 8.3 = ________________ mg/l $CaCO_3$

A - ml NaOH titrant used: ________________ ml
B - normality of titrant: ________________ N
C - ml portion of sample: ________________ ml

$$\frac{A \times B \times 50{,}000}{\text{ml sample portion}} = \text{Acidity}$$

TABLE III.11
DRY ATMOSPHERIC DEPOSITION SAMPLE RECORD

DATE: From ____________ @ ____________ to ____________ @ ____________

STATION NAME: ____

STATION NUMBER: ____________________ SAMPLE NUMBER: ________________

COMMENTS (Insects or other floating objects, etc.):

BOTTLE & SAMPLE WEIGHT: ________________ g (Use
EMPTY BOTTLE WEIGHT: ________________ g 400 ml
NET WEIGHT: ________________ g dist H_2O)

IS THE SAMPLER FUNCTIONING CORRECTLY? YES ____ NO ____

IF NOT, WHY?

TABLE III.12
PRESERVATION AND PROCESSING OF WET DEPOSITION SAMPLES

First Priority	Holding Max.
Total Solids: Cool to 4°C	14 days
Sulfate: Cool to 4°C	28 days
Total Phosphorus: Cool to 4°C, add H_2SO_4 to pH 2	28 days
Total Lead: Add HNO_3 to pH 2	6 months
(Multi-element scan can be conducted with the same sample as total Pb.)	
Second Priority	
Acidity: Cool to 4°C (not done at the LOH)	14 days
COD: Cool to 4°C, add H_2SO_4 to pH 2	28 days
Soluble P: Cool to 4°C, filter	48 hours
Third Priority	
NH_4: Cool to 4°C, add H_2SO_4 to pH 2	28 days
NO_2-N + NO_3-N: Cool to 4°C, add H_2SO_4 to pH 2	28 days
Total Organic N: Cool to 4°C, Add H_2SO_2 to pH 2	28 days
Other	
pH: Determine in the field	2 hours
Conductivity: Determine in the field	28 days

Atmospheric Deposition Sample Analyses

Table III.13 lists the constituents for which the wet and dry atmospheric deposition samples were analyzed. First priority analyses were conducted for all rains greater than 0.25 inch, second priority analyses for rains greater than 0.5 inch, and third priority analyses for rains greater than 0.75 inch. These priority groupings were necessary because of sample volume requirements. Total lead and total phosphorus analyses were conducted for all dry deposition samples. Lab error or insufficient volume reduced the number of analyses for total solids, COD and sulfate slightly.

The use of more than one detection limit for a given pollutant by the laboratory required discarding some concentration values for total and soluble phosphorus, total and suspended solids and sulfate. In all cases when dual detection limits were used, the higher limit values were discarded. One-half of the detection limit concentration was used for those analyses below detection.

The following discussion summarizes the wet and dry sample analyses procedures that were used during the project:

Wet Precipitation--

Sample Transfer to Erlenmeyer Flask--Remove the bucket lid and check sample for insects and/or large organic particles (these include leaves, twigs, bird droppings, etc.). Remove these with a pipet or clean teflon tweezers. Record any removals and possible contamination in the Wet Atmospheric Deposition Sample Record.

Using a bristle brush (polyethylene), slowly "scrub" the bottom and sides of the bucket to loosen adhering solids and settled particulates. Avoid sample agitation. The bristle brush should be soaked in a 600 ml beaker containing 10% hydrochloric acid previous to scrubbing. Rinse the brush three times with copious amounts of distilled water. Follow this procedure for every bucket. Careful handling of the sample is essential due to the easy contamination of rain samples. Using a clean funnel, transfer the sample to an Erlenmeyer flask and record volume on the sample record.

Sample Splitting--Dismantle the DECA sample splitter and wash all parts in a QED wash solution (6 ml QED to 1 gal. water). Rinse with distilled water three times. Assemble the splitter and place appropriate bottles into position (see sample splitting and constituent diagram, Figure III.8).

Priority analyses are indicated on Figure III.8. Depending on the total volume collected for a particular rain, some second and third priority analysis may have to be excluded. The priorities for analysis will be assigned after the volume of each sample (bucket) is known.

Sample Preservation and Filtration--Preserve COD, N-series, and total phosphorus samples with 12.5% sulphuric acid to a pH less than two. Refer to the preservation chart located in the lab for proper acid additions.

Filter soluble lead and soluble phosphorus samples. Place all processed samples in the refrigerator (maintained at 4°C) pending shipment.

TABLE III.13
LIST OF CONSTITUENT ANALYSES FOR WET AND DRY ATMOSPHERIC DEPOSITION SAMPLES

Dry Deposition:

Total Solids
Total Phosphorus
Total Lead
Sulfates
COD

Wet Deposition:	Volume Needed for Wet Deposition Sample to Analyze Each Constituent, ml .
First Priority:	
Total Solids	50
Total Phosphorus	50
Soluble Phosphorus	50
Total Lead	25
Second Priority:	
Sulfate	50
Soluble Lead	25
Nitrate Plus Nitrite	25
Ammonia	25
Acidity	40
Third Priority:	
Chloride	50
COD	50
Suspended Solids	100
Field Analysis:	
pH	40
Conductivity	60

Preserve total lead samples with HNO_3 to a pH 2.

Conductivity, Acidity and pH Determinations--Write the station name on top of the 250 ml bottle containing approximately 100 ml of sample. For acidity and pH determinations, 40 ml is used. This should be poured, without agitation, into a 100 ml beaker. The remaining 60 ml is for the conductivity measurement.

Use the YSI conductivity meter to measure conductivity. Pour 60 ml of sample into a 250 ml graduate cylinder and lower the probe into the sample far enough so the thermistor on top of the probe is covered with sample. Refer to the instruction manual for zero adjustment and use. Record conductivity on the Wet Deposition Log.

pH is determined using the 40 ml sample before the acidity titration begins. Calibrate the Orion pH meter (Orion Research - Ionalyzer Mod 407A) with pH 7 and pH 4 buffers. Place the 100 ml beaker with 40 ml of sample on an insulation pad on top of the stirrer. Drop in a small stir bar and switch onto low speed. Allow sample contact with probe, wait 2-3 minutes and turn off stirrer. Allow for stabilization, then read pH. Record in Wet Deposition Log.

To prepare titrant for acidity measurement mix 40 mls 0.02 Normal sodium hydroxide solution with 560 mls of deionized, CO_2 free water (obtained from "ultra pure" filter cartridge). This will result in a 0.0013N sodium hydroxide solution. This must be mixed fresh prior to titration, as low normality solutions are subject to relatively rapid changes. Use a 20 ml pipet for the 40 ml of 0.02N sodium hydroxide and a 500 ml volumetric flask for the first 500 ml of deionized water. The 20 ml pipet can then be used for addition of the remaining 60 ml of deionized water. Pour titrant slowly without agitation into the polyethylene feed bottle on top of the titration stand. Cap tightly.

The titration buret is self zeroing. To titrate fill the buret by turning the stopcock to the fill position. Turn the stirrer onto low speed and immerse the probe into the precipitation sample (it may already be immersed from the original pH reading). Use 0.5 ml additions of titrant until a pH of 7 is obtained. At that point, smaller additions may be required so the pH 8.3 end point is not exceeded. Record volume of titrant used, volume of sample titrated and normality of titrant in the "Wet Atmospheric Deposition Sample Record".

Calculate acidity using the formula:

$$\frac{A \times B \times 50{,}000}{\text{ml Sample Titrated}} = \text{Acidity (mg/l } CaCO_3\text{)}$$

Where: A = ml of NaOH Titrant Used
B = Normality of Titrant

Data Recording--Enter all appropriate data into the sample record and log.

Dry Precipitation --

Sample Transfer to DECA Splitter--Remove the bucket lid and check sample for insects and/or large organic particles (these include leaves, twigs, bird droppings, etc.). Remove with a teflon tweezers. Record any removals or contamination in the Dry Atmospheric Deposition Sample Record.

Pour 400 ml of deionized water (from "ultra pure" filter cartridge) into each of eight 625 ml bottles. Weigh each bottle (with water inside) on the Mettler P 1210 balance and record weights in the dry sample record. Code the top of each bottle with a number designation and record the number in the sample record for later reference.

Transfer the 400 ml of deionized water into the appropriate dry precipitation bucket. Using the bristle brush, scrub the sides and bottom of the vessel to loosen adhering solids. Scrub thoroughly until the entire inside is "clean".

The bristle brush should be soaked in a 600 ml beaker containing 10% hydrochloric acid previous to and between bucket scrubbing. Immerse the brush in a beaker of distilled water and then rinse three times under the distilled water tap after removing from the hydrochloric solution.

After each bucket is completely scrubbed, it can then be transferred directly into the DECA splitter.

Weigh all empty 625 ml bottles and record weights.

Sample Splitting--Follow the cleaning procedure described in Section B of the Wet Precipitation Processing Guidelines.

Refer to the Dry Precipitation Sample Splitting and Constituent Diagram (Figure III.9).

Sample Preservation--Preserve COD and total phosphorus samples with 12.5% sulfuric acid. Refer to the preservation chart for proper additions.

Preserve total lead sample with HNO_3 to a pH 2.

Place all processed samples in the refrigerator (maintained at 4°C) pending shipment.

Data Recording--Enter all appropriate data into the sample record and log.

ROOFTOP MONITORING

During the course of the Milwaukee NURP study, it was determined that an attempt to quantity the contributions of runoff pollutants from rooftops should be made. Therefore, in May of 1982, roof runoff monitoring program was started. The impervious area within the NURP study sites ranged from 50 percent at Congress to 100 percent at the Rustler study site. In many cases roofs that drain directly into storm sewer drainage systems can make up a large percentage of the directly connected impervious area (Table III.14).

TABLE III.14
CONTRIBUTION OF ROOFTOPS TO TOTAL WATERSHED IMPERVIOUS AREAS

Monitored Rooftops	Study Area	Total Watershed Area (Acres)	Total DCI* Area (Acres)	Total Rooftop Area (Acres)	Directly Connected Rooftop Area (Acres)	Contribution of Rooftop Area to Total DCI
Virgil	Burbank	62.6	31.7	11.31	2.71	11.9%
Virgil	Hastings	17.1	12.1	6.47	1.68	13.9%
Ewald	Congress	33.0	12.8	4.96	1.39	10.9%
Ewald	Lincoln	36.1	15.7	6.41	1.47	9.4%
	Wood Center	44.9	32.7	10.58	7.05	21.6%
Sylvester	Residential**			4.73	1.56	
Wood Hosp.	Commercial**			5.85	5.49	
	State Fair	29.0	20.3	7.71	5.73	28.2%
Sylvester	Residential**			2.65	0.77	
WA City Hall	Commercial**			5.06	4.96	
	Post Office	12.4	12.1	0.04	0.04	0.3%
	Rustler	12.4	12.4	5.22	5.22	42.1%

*DCI: directly connected impervious area

**not located in the study areas

Rooftop Monitoring Site Descriptions

Three residential and two commercial-industrial rooftops were monitored. The monitored residential rooftops were sloped at angles of 20 or 45 degrees and were surfaced with asphalt shingles. The monitored commercial-industrial roofs were flat and surfaced with tar and pea gravel. The residential roofs were drained with a gutter system, or drained directly onto the ground. The commercial-industrial roofs were drained in sections by gentle sloping to an internal or external drain system. The residential roofs ranged in height from 10 to 20 feet and the commercial sites were 30 to 40 feet high.

All the sites were located near or within a NURP stormwater runoff watershed. The locations are listed as follows:

Site Name:	Residential (R) Commercial (C):	Associated Watershed:
Sylvester	R	State Fair, Wood Center
Ewald	R	Lincoln, Congress
Virgil	R	Hastings, Burbank
Wood Center	C	Wood Center
West Allis City Hall	C	State Fair

The Wood Center and West Allis City Hall commercial-industrial sites were located on the same rooftops as the atmospheric deposition sites. Both flat roof sites (Wood Center and West Allis) are located in commercial-high density residential areas. Both roof drainage systems are connected directly to storm water sewerage systems. Both roofs are pea gravel and tar, and have had no major repairs or resurfacing in over 10 years. The sites are approximately 2.5 kilometers apart.

The West Allis site is a relatively new building built in the late 1960's. The roof is drained through the building via cast iron pipes. The drainage area of the pipe samples is 158 square meters. The West Allis wet dry deposition collector is also on the same roof. The West Allis rooftop samples were collected in the basement of the building, through an opening in the drainpipe provided as a clean out space. During a runoff event, the sampling bottles (provided by the State Laboratory of Hygiene for the NURP project) were held in the flow of water within the pipe until filled. The samples were then labeled, the appropriate preservative added, iced, and shipped to the State Laboratory of Hygiene for analysis.

The Wood Center site is an older building, well over 40 years old. The roof is drained along the outside of the building, via the standard galvanized pipe found draining most roofs. The drainage area of the pipe samples is 128 square meters. The rooftop runoff is unconnected to any storm water drainage system. The samples were collected at ground level by simply holding the water sample bottles (provided to the NURP project by the State Lab of Hygiene) in the flow of water. The samples were labeled, appropriate preservative added, iced, and shipped to the State Lab for analysis.

Rooftop Runoff Sampling Experimental Design

The experimental design aspect of the rooftop sampling experiments involved sizing the sample containers for the known roof areas and expected runoff volumes.

Sampling is accomplished by means of a trough-like device which fits in the rain gutter near the downspout. The length of the sampler is variable and is determined for each roof. The maximum volume to be sampled is predetermined by the container volume and the maximum rain event size to be normally sampled.

$$S = \frac{C(61025)}{R(E_m)}$$

R = roof span (inches)
S = sampler length (inches)
C = container volume (liters)
E_m = event maximum (inches of rain)

Table III.15 shows these expected sample volumes for different rooftop areas and sample lengths.

Rooftop Runoff Sample Collection

Sampling was accomplished with a trough-shaped sampler which fits in the rain gutter adjacent to the downspout (see Figure III.9). A 9.5 mm tygon hose is attached to the side of the sampler. The hose extends into the downspout, out a drilled hole (approximately one meter from the ground) and into the sample container (five-gallon wide-mouth polyethylene). The downspout hole and container mouth were sealed to prevent leakage.

The samplers were constructed of new galvanized steel, identical to that used in most gutter construction. It is waterproofed at the seams with silicone caulking. Galvanized steel was used, rather than a chemically neutral material because the gutters may also contribute a pollutant load to the rooftop runoff that must be included.

The length of the sampler was variable according to roof dimensions, as discussed previously. This results in a small sampling area on each roof which represents the entire roof. The actual volume of sample obtained may change within two similar storms as a result of wind direction and velocity, and rain intensity.

Flat rooftops, from the commercial-industrial sites, were sampled as instantaneous grab samples rather than as composite samples, as described earlier. Actual monitoring began in mid-October, 1981 and concluded July 1, 1982.

Rooftop Runoff Sample Processing

Figure III.10 is a flow diagram showing the sample processing for the rooftop analyses.

TABLE III.15
SAMPLE VALUES FOR DIFFERENT SIZE ROOF AREAS AND SAMPLE R LENGTHS
(ASSUMING A ONE INCH RAIN)

A 25 ft. roof with an 18 in. sampler will yield = 23.4 gal.
A 20 ft. roof with an 18 in. sampler will yield = 18.7 gal.
A 15 ft. roof with an 18 in. sampler will yield = 14.0 gal.
A 10 ft. roof with an 18 in. sampler will yield = 9.4 gal.

A 25 ft. roof with an 12 in. sampler will yield = 15.6 gal.
A 20 ft. roof with an 12 in. sampler will yield = 12.5 gal.
A 15 ft. roof with an 12 in. sampler will yield = 9.4 gal.
A 10 ft. roof with an 12 in. sampler will yield = 6.2 gal.

A 25 ft. roof with an 9 in. sampler will yield = 11.7 gal.
A 20 ft. roof with an 9 in. sampler will yield = 9.3 gal.
A 15 ft. roof with an 9 in. sampler will yield = 7.0 gal.
A 10 ft. roof with an 9 in. sampler will yield = 4.6 gal.

A 25 ft. roof with an 8 in. sampler will yield = 10.4 gal.
A 20 ft. roof with an 8 in. sampler will yield = 8.3 gal.
A 15 ft. roof with an 8 in. sampler will yield = 6.2 gal.
A 10 ft. roof with an 8 in. sampler will yield = 4.2 gal.

FIGURE III.9

ROOFTOP RUNOFF MONITORING SYSTEM

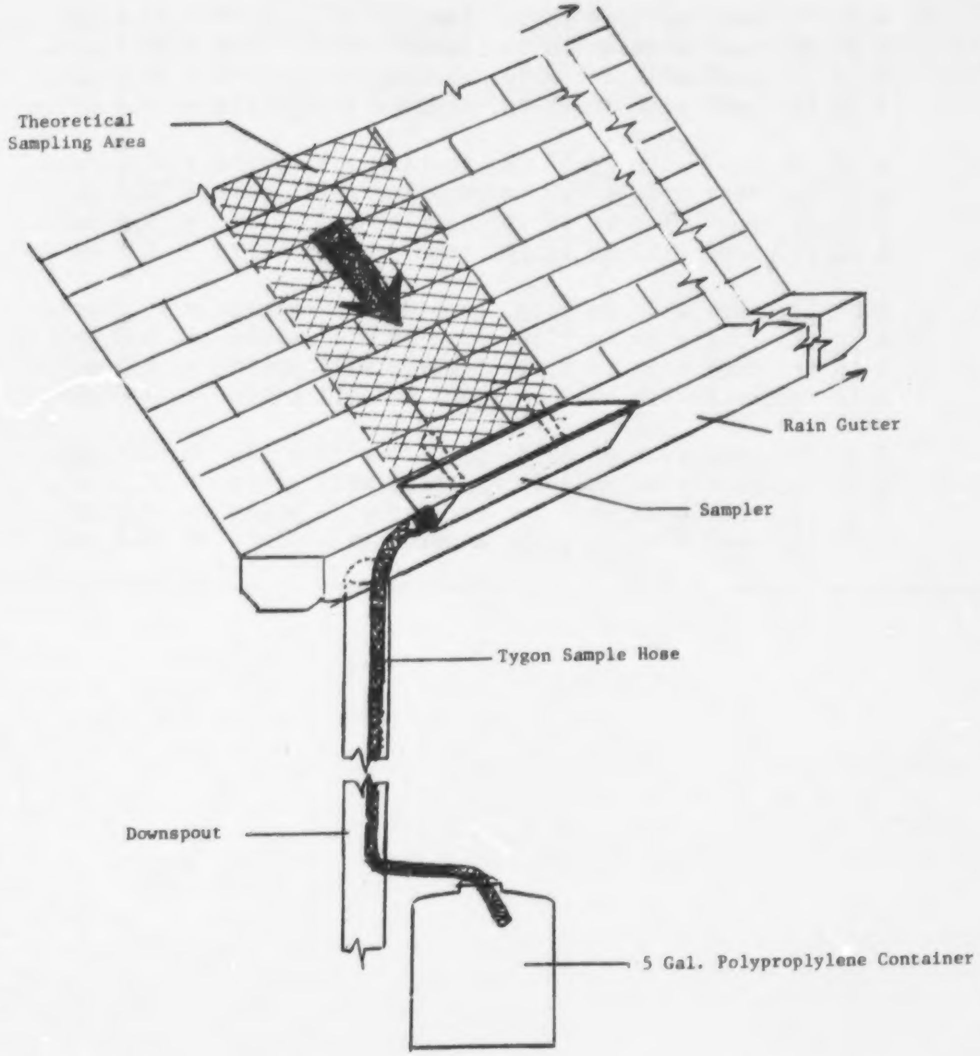
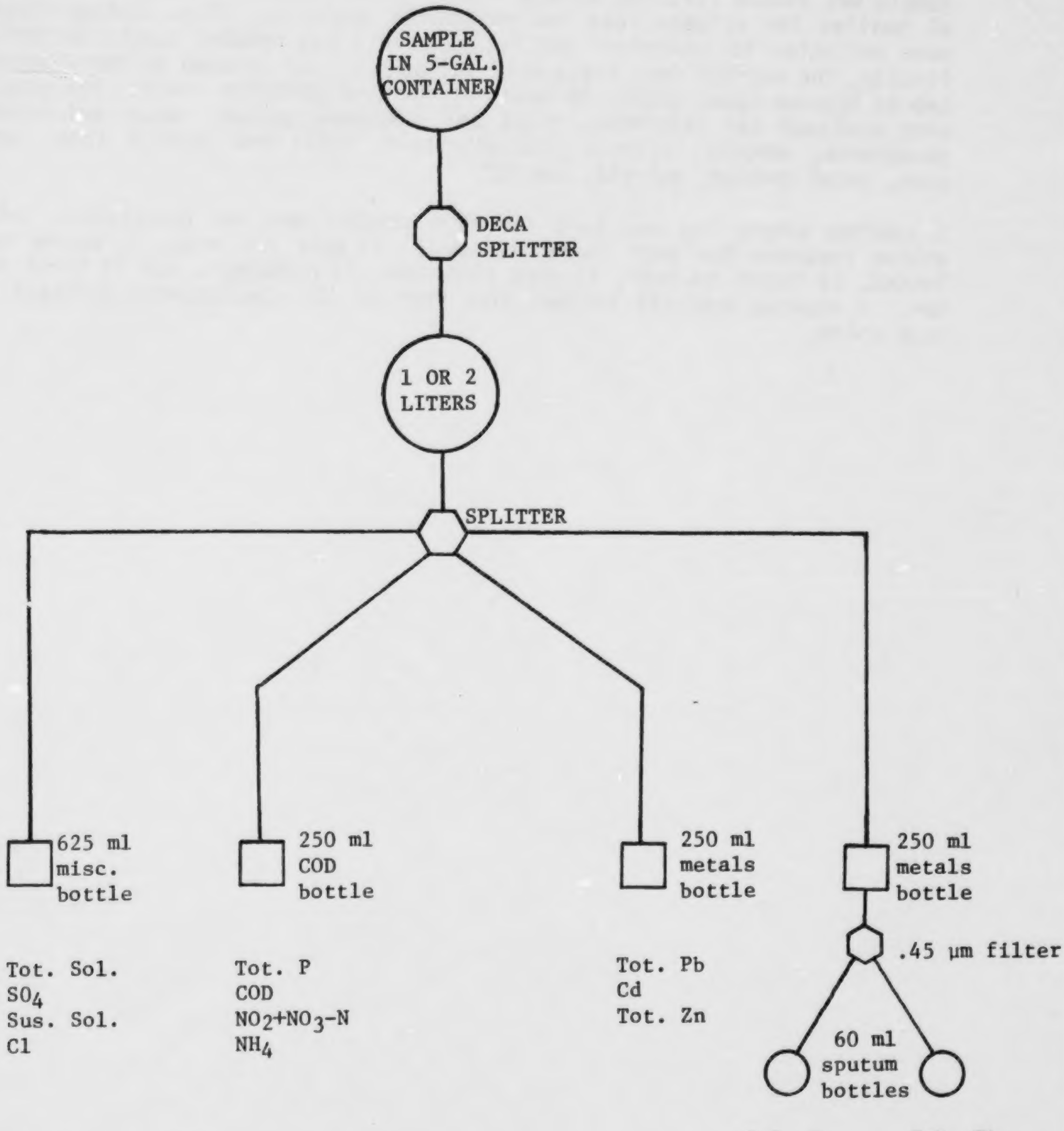

Theoretical Sampling Area
Rain Gutter
Sampler
Tygon Sample Hose
Downspout
5 Gal. Polyproplylene Container

FIGURE III.10

ROOFTOP RUNOFF SAMPLE PROCESSING FLOW DIAGRAM


SAMPLE IN 5-GAL. CONTAINER
DECA SPLITTER
1 OR 2 LITERS
SPLITTER
625 ml misc. bottle
250 ml COD bottle
250 ml metals bottle
250 ml metals bottle
Tot. Sol.
SO_4
Sus. Sol.
Cl
Tot. P
COD
NO_2+NO_3-N
NH_4
Tot. Pb
Cd
Tot. Zn
.45 μm filter
60 ml sputum bottles
Sol. P
Sol. Pb

Samples were collected and processed within 24 hours of each storm. Residential sample composites were processed, first by splitting the sample with the USGS DECA splitter to reduce the sample to a representative smaller portion. This sample was split again into four laboratory bottles. 120 mls of sample was vacuum filtered through a 0.45 micron membrane filter into two 60 ml bottles for soluble lead and phosphorus analysis. Flat rooftop samples were collected in laboratory bottles which did not require sample splitting. Finally, the samples were preserved, put on ice, and shipped to the Wisconsin Lab of Hygiene (LOH) within 24 hours of the precipitation event. The samples were analyzed for chlorides, total and suspended solids, total and soluble phosphorus, ammonia, nitrate plus nitrite-N, total and soluble lead, total zinc, total cadmium, sulfate, and COD.

A rooftop sample log was kept for each station and the descriptive information recorded for each storm included: 1) date and time, 2) volume collected, 3) inches of rain, 4) wind direction, 5) windspeed, and 6) field number. A rooftop analysis log was also kept of the constituents analyzed for each storm.

CHAPTER IV
URBAN STORMWATER MODELS

INTRODUCTION

This chapter describes two models that were developed during this project: WURM (Wisconsin Urban Runoff Model) and SLAW (Street Load and Washoff Model). The WURM model was developed to estimate urban nonpoint source pollution loading values for different street sweeping frequencies. It was calibrated and verified with the data collected at the Milwaukee NURP sites. The SLAW model was developed in an attempt to obtain a more sensitive indication of street dirt loadings and street surface washoff for different conditions. It also used the data from the specific Milwaukee NURP monitoring effort.

This chapter describes these models; their basis, input requirements, verification procedures, and typical output.

WURM (WISCONSIN URBAN RUNOFF MODEL) DESCRIPTION

A mass balance model was developed by Novotny (1983) to examine the effects of street cleaning on urban runoff quality. This model, called "WURM" for Wisconsin Urban Runoff Model, was calibrated and verified by the two and one half years of site data at the eight Milwaukee NURP study areas. The model was used for sensitivity analyses to examine the effects of several site and street cleaning equipment variables on runoff quality. This report section briefly summarizes the model assumptions. Refer to Novotny's report (1983) for a more complete description.

The WURM model is limited in the sense that only surface nonpoint source pollution and only rainfall seasons (spring, summer, and fall) can be simulated. Subsurface and ground water pollutants, channel processes, and snowfall season pollutants cannot be evaluated. The water quality constituents that are specifically considered include suspended solids (SS), volatile suspended solids (VSS), nitrogen (N), phosphorus (P), and lead (Pb), or up to four conservative pollutants.

Model Structure

A simplified flow chart of the WURM model is shown in Figure IV.1. The model data input block includes: land use and soil texture, sweeping equipment characteristics, atmospheric and traffic effects, and weather conditions. As indicated in Figure IV.1, the WURM model operates sequentially by reading daily meteorological data and printing seasonal or yearly mass balances as it proceeds through the entire simulation period. The output of the WURM model contains a mass balance table that includes: (1) initial pollutant amounts, (2) end pollutant amounts, (3) pollutant inputs (dry deposition, wet deposition, soil, traffic, and litter inputs), and (4) pollutant outputs (swept out pollutants and runoff washout). The model also provides daily surface accumulation flow of pollutants in the curb storage and the volume and pollutant concentrations of the runoff.

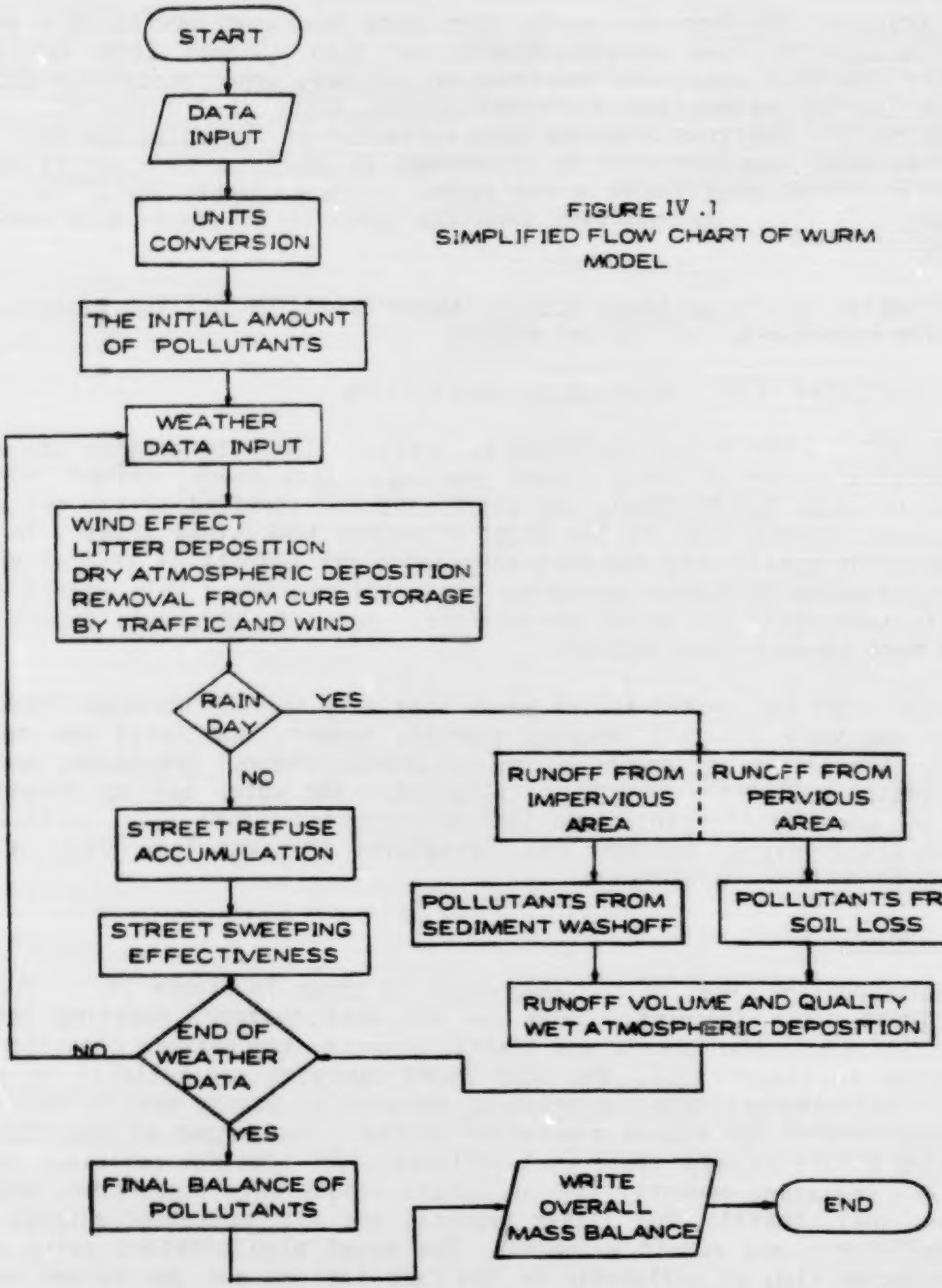

START
DATA INPUT
UNITS CONVERSION
THE INITIAL AMOUNT OF POLLUTANTS
WEATHER DATA INPUT
WIND EFFECT
LITTER DEPOSITION
DRY ATMOSPHERIC DEPOSITION
REMOVAL FROM CURB STORAGE
BY TRAFFIC AND WIND
RAIN DAY
YES
NO
RUNOFF FROM IMPERVIOUS AREA
RUNOFF FROM PERVIOUS AREA
STREET REFUSE ACCUMULATION
POLLUTANTS FROM SEDIMENT WASHOFF
POLLUTANTS FROM SOIL LOSS
STREET SWEEPING EFFECTIVENESS
RUNOFF VOLUME AND QUALITY
WET ATMOSPHERIC DEPOSITION
NO
END OF WEATHER DATA
YES
FINAL BALANCE OF POLLUTANTS
WRITE OVERALL MASS BALANCE
END

FIGURE IV.1
SIMPLIFIED FLOW CHART OF WURM MODEL

The WURM model is composed of the following subcomponents:

Deposition and Accumulation of Pollutants on Street Surfaces --
In the WURM model, the accumulation concepts are based on Novotny and Chesters' (1981) refuse accumulation model. The input of pollutant A, with units in g/m-day, can be expressed by the following equation:

$$A = \frac{(SW)}{(2)} * (ATDD + LIT) + (C) * (TD) * (RC)$$

where SW is the street width in meters

ATDD is atmospheric dry deposition rate in g/m^2-day or ton/km^2-day

LIT is litter deposition rate in g/m^2-day,

C is traffic emission rate in g/Km-axle,

TD is traffic density in 1000 axles/day, and

RC is road condition ranging from 0 (very poor) to 10 (excellent)

The user of the program has an option to input a constant removal coefficient, for each simulated land use.

In the WURM model, particle sizes were lumped into three ranges: fine ($<$ 0.065mm), medium (0.065 to 2mm), and coarse ($>$ 2mm).

Street Cleaning Effectiveness --
The remaining amount of street surface pollutants (P) in a given size range after street cleaning was estimated by the following equation:

$$P = (P_o) * (1-R)$$

where P_o is the initial amount of pollutants in the given size range, and

R is sweeping efficiency for the given size range; it is an empirical value.

Street Dirt Washoff --
The WURM; model uses a modified Sartor and Boyd's (1972) washoff concept to estimate washoff of pollutants by surface runoff in impervious areas:

$$P_t = P_o \, (1-e^{K_u rt})$$

where P_t is the mass of pollutant removed by rain during the interval t, and

P_o is the initial mass of pollutants in the curb storage.

Based on the assumption that 90 percent of a pollutant can be removed by a 12.7mm/hr (0.5 inch/hr) peak rain intensity lasting five minutes, the K_u value recommended by Sartor and Boyd was 0.19 (if the rain intensity was in mm/hr).

In the WURM model, the washoff is particle size dependant, depending on the magnitude of the availability factor, A. If A is less than 1.0, the 1-A fraction of coarse and medium particles remain on the surface and are not washed off by the runoff.

Runoff Volume --
The excess rain runoff from impervious surfaces is determined by the following equation:

$$Q_i = P - DS$$

where Q_i is the volume of runoff in cm or inch,

P is rainfall in cm or inch, and

DS is the depression storage in cm or inch.

The depression storage of impervious surfaces was estimated by Tholin and Keifer (1960) for the Chicago area as being 1.6mm (1/16 in). This relationship does not consider evaporation.

The excess rain from an impervious surface may overflow onto a nearby pervious area. This portion of runoff, which is not directly connected to the drainage system, is added to the rainfall on adjacent pervious surfaces.

For estimating the runoff from pervious areas, the WURM model uses the Soil Conservation Service (SCS) method. In the SCS method, the relationship between rainfall and runoff can be expressed by the formula:

$$Q = \frac{(P-0.2S)^2}{P+0.8S}$$

where Q is the runoff volume,

P is the precipitation or rain volume, and

S is the potential maximum retention defined as:

$$S = \frac{1000}{CN} - 10$$

Where CN is runoff curve number.

Runoff occurs only if $P > 0.2S$.

The CN value is an index representing both meteorologic and watershed characteristics. The rainfall volume or the rain record during a preceding period, changes the antecedent soil moisture and in this way affects infiltration.

The soil type, land use, and the hydraulic condition of the land cover are the watershed factors affecting the selection of the runoff curve number. The SCS method divides soils into four groups as A, B, C, and D according to the following classification (Soil Conservation Service, 1982):

Group A:	deep sand, deep less, aggregated silts
Group B:	shallow less, sandy loam
Group C:	clay loams, shallow sandy loam, soils low in organic content, and soils usually high in clay
Group D:	soils that swell significantly when wet, heavy plastic clays, and certain saline soils

According to the different land-use, treatment or practice, and hydraulic conditions of different soil groups, the approximate CN is given by the SCS.

Soil Erosion from Previous Areas --
The WURM model uses the Universal Soil Loss Equation (USLE) for estimating soil losses from pervious areas. This equation is:

$$A = R * K * LS * C * P$$

where A is the sediment loss per hectare per storm,

R is the rainfall erosivity factor,

K is the soil erodability factor,

LS is the soil slope-length factor,

C is cover factor, and

P is erosion control practice factor.

The soil erodability factor, K, can be estimated by a soil erosion nomograph. This method requires determination of five parameters: percent silt + fine sand (0.05 to 0.1mm fractions), percent sand (> 0.1mm), percent organic matter, texture class, and permeability. The slope-length factor, LS, is a function of the overall runoff length and slope. The vegetation cover factor, C, is an index of ground cover condition, soil conditions, and general management practices on the rate of erosion. In a construction area, the C value could reach maximal values of 1.0.

The erosion control practice factor, P, is an index expressing the erosion control effectiveness of various practices. In the absence of such practices, the P factor is 1.

Model Inputs

For modeling purposes, the watershed characteristics can be grouped into: land use data, hydrological characteristics, soil and surface cover data, and traffic characteristics. Chapter II described the land-use and hydrological data for each watershed. Inasmuch as most of the soils in the Milwaukee Metropolitan Area are in the silt and clay loam category, soil data for the study areas are quite similar to each other.

In the WURM model, pollution inputs include: wet and dry atmospheric deposition, litter deposition, and traffic inputs. In the monitoring program, atmospheric and street surface contaminant deposition was measured. The monitored results were original input data for the modeling work, or the data against which the model outputs were tested (calibration and verification).

The atmospheric deposition rates were investigated during the 1981-1982 study period. The solids from dry atmospheric deposition are one of the major sources of the fine particles in the street surface contaminants.

The original litter deposition input data, (such as the street litter composition and the initial amount of particulates) were estimated from monitored data. Higher litter composition values were used to reflect enrichment of the runoff by the pollutants. For example, the enrichment ratio for organics ranged from 2 to 3, for phosphorous from 3 to 8, and the lead enrichment was between 1 to 1.5.

During this study, traffic inputs were not directly measured. Literature data was used for generating the traffic input, based on Shaheen (1975). For the WURM model, it was assumed that all solids generated by traffic would be in the medium particle size range.

Daily weather data inputs included temperature, wind velocity, and rainfall. The data input format also included corrective factors for litter deposition rates and organic content that can adjust pollution inputs for seasonal conditions. Rainfall data were entered in hourly intervals. The data were provided by the observation stations located at each experimental site. The wind velocity values were entered as average daily wind. The wind velocity measurements were taken at the Mitchell Field Airport by the NOAA and may not reflect the actual wind velocity at each study site, but, fortunately, the model is not extremely sensitive to the wind input. Milwaukee has a continental climate as described in Chapter II. In this study, the consecutive climatological data was divided into three seasons that excluded winter.

Calibration And Verification Of The Model

For each watershed, the monitoring program provided the following information:

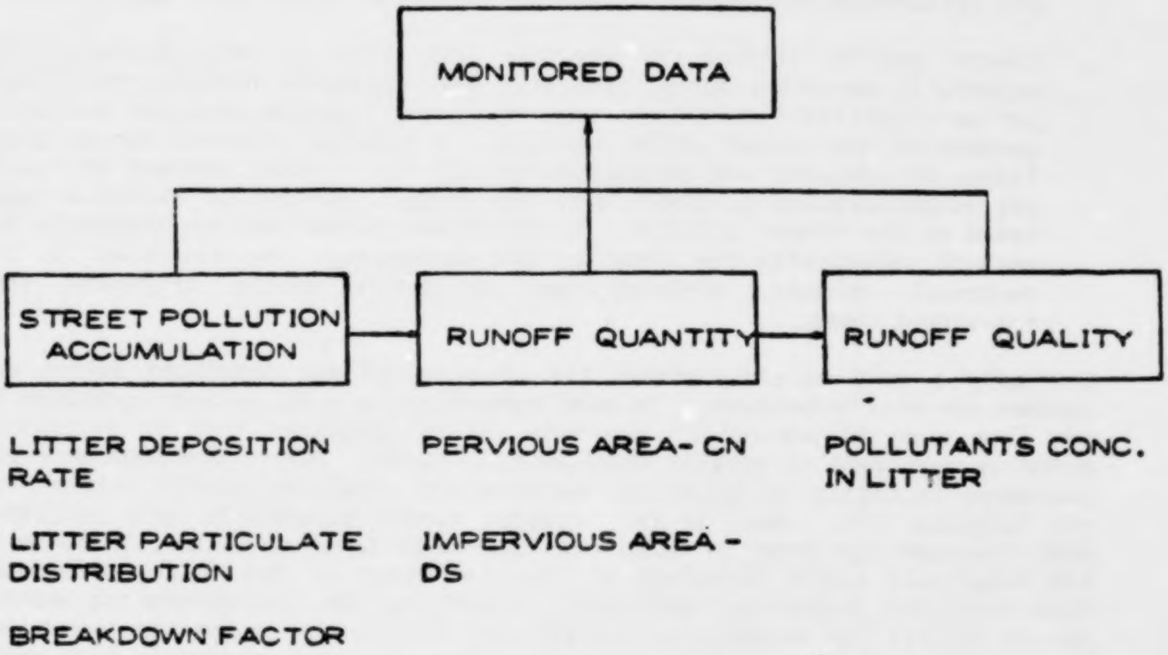
- atmospheric deposition rates (wet and dry) of pollutants;
- pollutant accumulations on street surfaces. The particle and pollutant accumulation was reported in several particle fractions and for organics; and
- runoff quality from all watersheds.

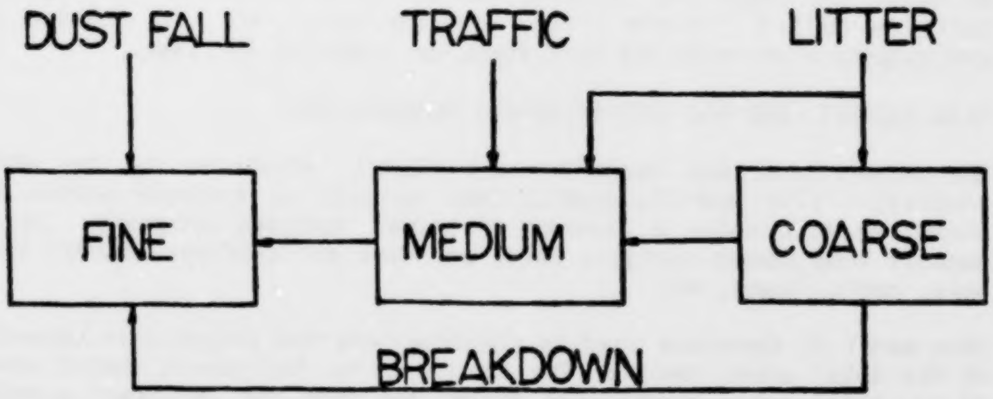
The calibration process proceeded as follows (Figure IV.2):

- The model generated street pollutant accumulation values were matched against the monitored data. Three adjustable variables were involved in

FIGURE IV.2

CALIBRATION PROCESS


MONITORED DATA
STREET POLLUTION ACCUMULATION
RUNOFF QUANTITY
RUNOFF QUALITY
LITTER DEPOSITION RATE
LITTER PARTICULATE DISTRIBUTION
BREAKDOWN FACTOR
PERVIOUS AREA- CN
IMPERVIOUS AREA - DS
POLLUTANTS CONC. IN LITTER


DUST FALL
TRAFFIC
LITTER
FINE
MEDIUM
COARSE
BREAKDOWN

the calibration: litter deposition rate, the litter distribution between coarse and medium particulates, and daily breakdown of particulates into finer fractions.

- When an adequate fit of street accumulation data was obtained, the calibration then proceeded to matching runoff quantity for storm events with the monitored data. The adjustable parameters were the Runoff Curve Number (CN) for pervious areas and depression storage for impervious areas. No significant deviation from estimated values occurred and runoff calibration was generally satisfactory after a few minor adjustments.

- Runoff quality calibration was the last step in this process. The adjustable variables during this step were pollutant contents of litter, yet no significant deviations were permitted from the measured pollution content of the street solid deposits. A problem occurred during simulation of organics and phosphates because the organic content of runoff was disproportionally higher than the organic content of solids accumulated on the street surfaces. An enrichment factor had to compensate for washoff selectivity for organics and phosphates. As discussed in the technical volumes, organics and phosphates mostly originate from non-street areas.

Generally a good to satisfactory fit of measured and simulated values was reached for most watersheds. In such comparisons a + 50 percent agreement of not less than 80 percent of the data points (provided that no systematic error is detected) is usually considered adequate. Severe problems were encountered in trying to match the measured and simulated runoff volumes for the Congress site. Most of the measured runoff volumes in this watershed were more than one order of magnitude lower than those simulated, in spite of the relatively simple hydrology of the area (most of the runoff originates from connected impervious surfaces). Modifying the appropriate parameters during calibration (depression storage and fraction of connected impervious area) would lead to unrealistically low values of these parameters that would grossly deviate from those ascertained in situ. After discussing the problems with the field engineers, it was realized that backwater from Lincoln Creek had severely affected the measured flow. Therefore, no comparisons of measured and simulated runoff volumes and concentrations were made. However, by using the experience gathered on the other watersheds and analyzing the paired watershed (Lincoln Creek) simultaneously, the mass balance of inputs and outputs along with the unit loads was computed for 1981.

SLAW (STREET LOAD AND WASHOFF MODEL) DESCRIPTION

The Street Load and Washoff model (SLAW), developed by the WDNR, is a simplistic site specific model, that is used to estimate street loads and street washoff under a variety of street sweeping programs. It estimates washoff from street surfaces only, and does not consider washoff from driveways, roofs, lawns, etc.

This model is therefore used to consider only the street dirt washoff portion of the total urban runoff. The importance of the street runoff contribution to the total urban runoff load varies for both the pollutant considered and the rain conditions. For small storms, most of the runoff volume originates from streets, but for large storms, runoff volume from pervious areas can be more important than the street runoff portion.

Some pollutants (most notably lead) are more closely associated with street runoff. Pervious areas contribute relatively small quantities of these pollutants under most rain conditions. Other pollutants (such as most nutrients) originates mostly from pervious areas for most runoff conditions. Street surface runoff rarely is an important source for these pollutants. This model is therefore used to consider the effects of street cleanliness on street runoff quality and not the effects of street cleanliness on total runoff quality. It is a useful tool to identify the maximum effects and sensitivity of various components of alternative street cleaning programs.

Principle Model Components

The model operates on three primary functions related to street dirt: daily street dirt accumulation, street sweeper effectiveness and rainfall washoff. Each of these are discussed in turn.

Daily Street Dirt Accumulation --

SLAW relies upon a set of daily net accumulation rates that vary with each site and particle size. It does not incorporate daily deposition and resuspension rates, and therefore cannot be used as a pollutant source mass balance model. Daily accumulation rates are used for fine (less than 0.125 mm), medium (0.125 - 2.0 mm) and coarse (more than 2.0 mm) size fractions. These are subdivided further and distributed among the respective subgroup particle sizes (< 0.031, 0.031 - 0.063, 0.063 - 0.125, 0.125 - 0.25, 0.25 - 0.5, 0.5 - 1.0, 1.0 - 2.0, 2.0-4.0, and greater than 4.0 mm) according to the average particle size distribution that was measured at each site. For example, assume that the fine accumulation rate is 0.5 gram/curb - meter/day, and that the three particle sizes within the fine group (< 0.031, 0.031 - 0.063, 0.063 - 0.125 mm) comprise 20, 15 and 10 percent of the average total sample weight respectively (exclusive of grass and leaves). The entire group comprises 45 percent of the total sample weight. The daily accumulation rate for the 0.031 mm size fraction would be approximately 0.5 X 20 / 45, or 0.22 grams/curb - meter/day. Similarly, the daily rates for the two larger size fractions would be 0.17 and 0.11 grams/curb - meter/day, respectively. The street surface loading in each particle size is increased each day by the calculated rate. The fine, medium and coarse accumulation rates are calibrated in SLAW.

Street Cleaner Removal Effectiveness --

SLAW uses a combination of two expressions of street sweeper effectiveness that were established in this project (Volume I, Chapter V). First, the total amount removed by sweeping (TR) is calculated using site specific regression equations derived from street sweeping data. As noted in Volume I, at low initial street loads, street sweeping is not very effective and may in fact increase available street loads. If, because of low initial street loads, TR is less than zero, the removal function terminates at this point, and the street loads remain unaffected by sweeping. If TR is greater than zero, the individual particle size loads are each multiplied by the average fraction removed by sweeping (as given in Volume I, Chapter V). These interim individual particle size removals are then summed to derive a total interim removal (IR). The individual removals are then multiplied by the ratio of TR/IR, so that the sum of the adjusted individual removals equals TR. Resulting street loads are then determined by subtracting the individual removals from the respective initial particle size loads.

Rainfall Washoff --

SLAW uses a very simple rainfall washoff function. For every event larger than a tenth of an inch, the washoff is determined by multiplying the initial street load (by particle size) by the average net fraction removed by rain (Volume I, Chapter V). All events larger than a tenth of an inch have the same effect on the street load, regardless of the magnitude and intensity of the event. This simple assumption was chosen because, at the only site where a significant relationship was found between street load, rainfall and washoff (alpha = .05), adding rainfall magnitude and intensity to the multiple regression equation only increased the regression coefficient from 0.98 to 0.99. All events less than a tenth of an inch of rain are considered to have no impact on street loads. The tenth of an inch cutoff was chosen based on observation and professional judgement.

Model Inputs

SLAW requires four sets of site specific information:

- Average particle size distributions, exclusive of grass and leaves.
- Daily accumulation rates for fine, medium and coarse particle sizes.
- Average street sweeper removal effectiveness, by particle size: A regression equation defining the relationship between total initial street load and total amount removed by street sweeping.
- Average rainfall washoff rates, by particle size.

In addition, there are several run time options that allow for manipulating the street sweeping program. They include the initial total street load at the beginning of the modeling period, the street sweeping frequency, and the period of modeling (inclusive start and stop days, March through September).

Finally, a rainfall record is also required by the model. Four "years" of randomly generated rain data were developed and used in the modeling efforts, to compensate for the sensitivity of the street sweeping / rainfall washoff interaction to the frequency and timing of rainfall. For each month of March through September, a number of rain dates were randomly chosen, corresponding to the long-term average number of events per month with more than a tenth of an inch of rain. All modeling results used in this study were averaged over four runs of the model, using the four sets of rain data.

Model Operation

At the onset of a modeling run, the initial total street load is subdivided into the individual particle sizes according to the average particle size distribution. Also, the fine, medium and coarse accumulation rates are further subdivided into the individual particle size accumulation rates, also according to the average particle size distribution.

The model then proceeds to loop through the modeling period, from the first day until the last. On each day, the following scenario occurs. If there is a rainfall larger than a tenth of an inch on that day, the washoff is calculated (by particle size), and the street load is appropriately reduced. If sweeping had been scheduled for that day, then, if the sweeping frequency is once a week or more often, the sweeping is canceled, or, if the frequency is less often than once a week, the sweeping is postponed until the next day. If it did not rain on that day, and if sweeping is scheduled for that day, sweeper removal is calculated and applied. In any event, whether it has rained or been swept, or neither, the street loads are increased by the daily accumulation rates, and the model proceeds to the next day.

SLAW schedules sweeping at regularly set intervals (every N days). It does not recognize nor discriminate for weekends or holidays (but it does pay union wages). If a sweeping event is postponed because of rain, all subsequent sweepings are likewise postponed. For example, if the sweeping frequency is every 14 days, and if it rains on June 7th when it had been "scheduled" to be swept, that sweeping is postponed until the 8th, and the following sweeping occurs 14 days later on the 22nd. The first day of sweeping at the onset of the modeling period is determined by halving the sweeping frequency. If the sweeping frequency is every 14 days, the first day of sweeping would be 7 days into the sweeping period.

The model calculates and summarizes the total amounts washed and swept off the streets, and the total numbers of rainfalls and sweepings.

Model Calibration

The model was calibrated using 1981 street load, sweeping and rainfall data. Using this data, the fine, medium and coarse accumulation rates were adjusted until the range of total loads and the distribution of the fine, medium and coarse fractions within the total loads, approximated the 1981 data (Figures IV.3 through IV.8). The accumulation rates that were required to do this were significantly greater than were calculated for Congress and Hastings, and less than for State Fair. Because the washoff comparisons at the Rustler sites indicated a net gain in loadings in so many particle sizes, the model was not attempted for these sites.

FIGURE IV.3

COMPARISON OF MEASURED AND ESTIMATED STREET LOADS AT STATE FAIR

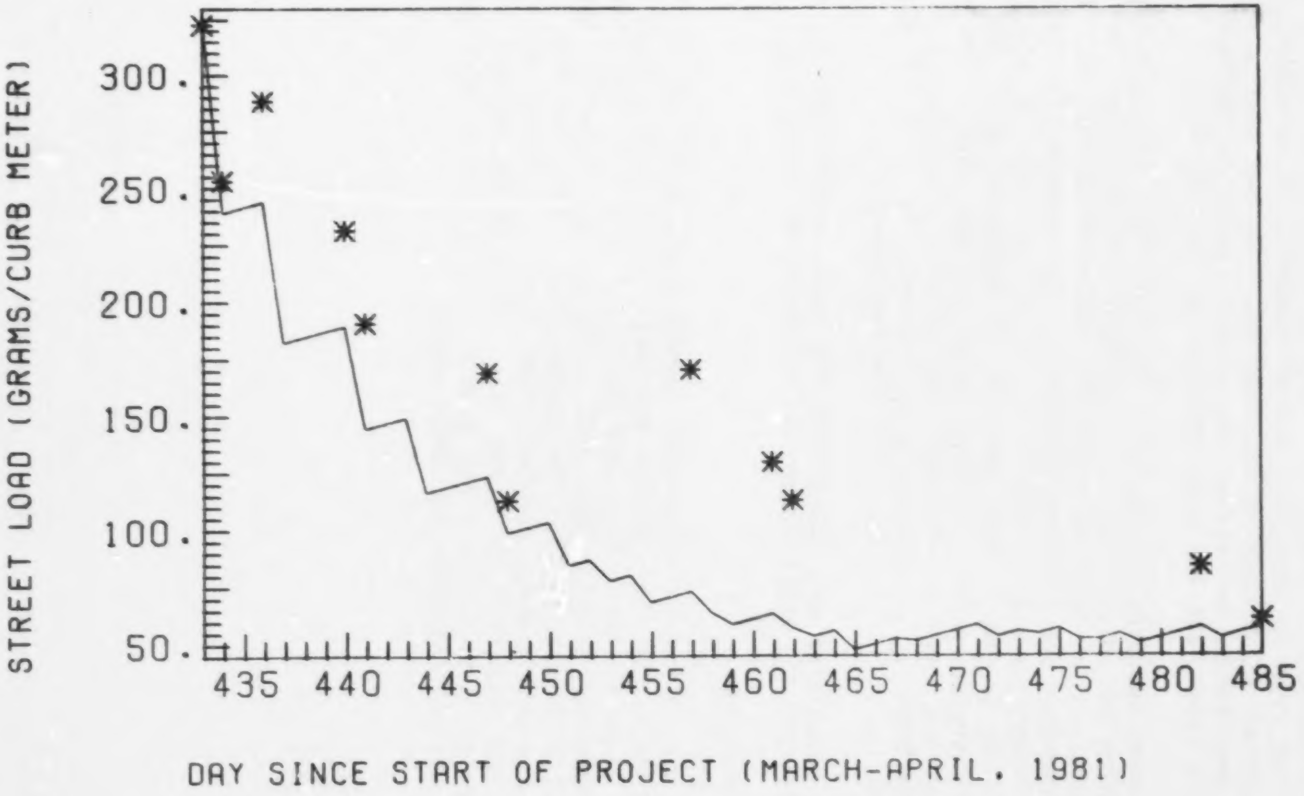
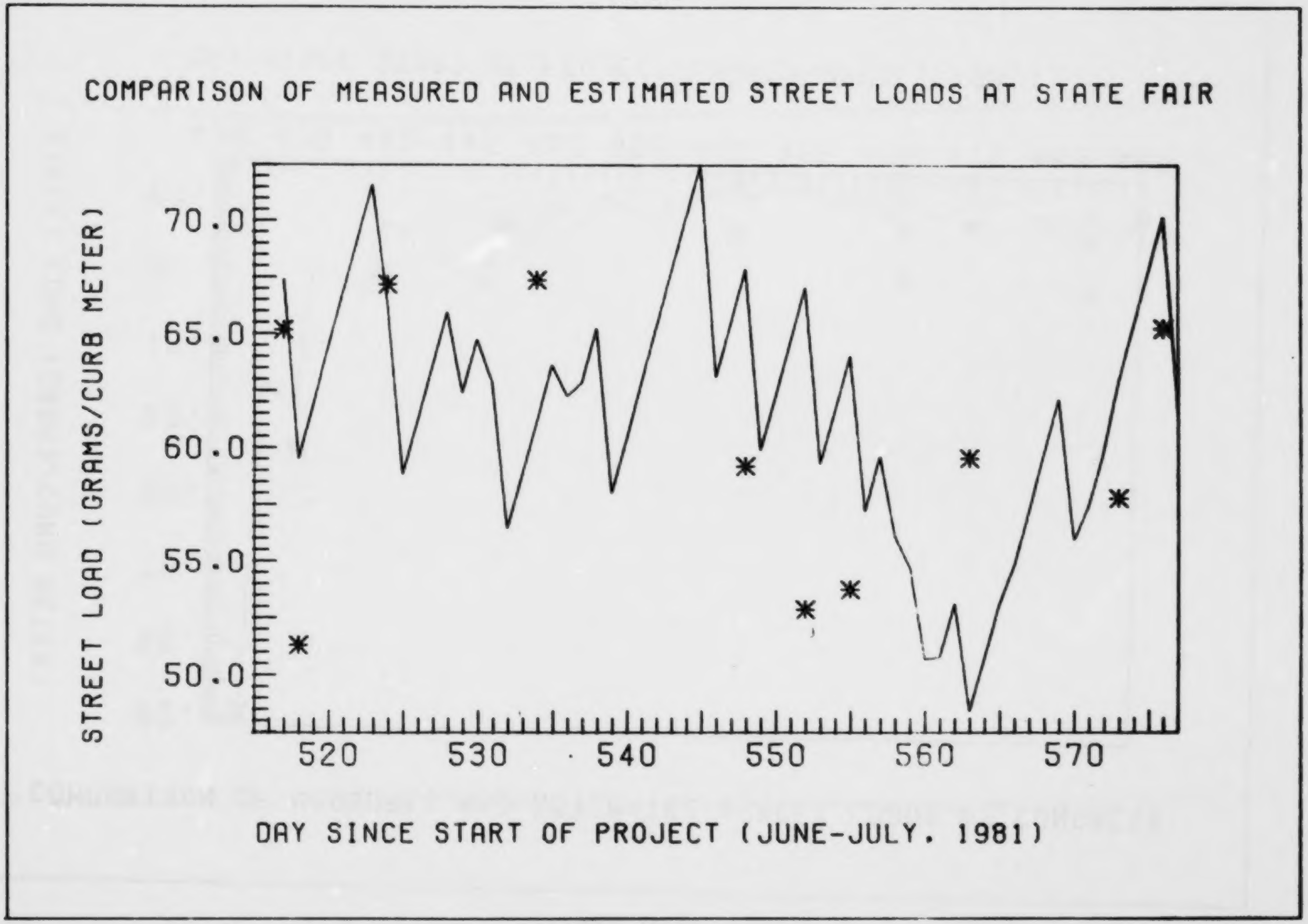


FIGURE IV.4



COMPARISON OF MEASURED AND ESTIMATED STREET LOADS AT STATE FAIR

FIGURE IV.5

COMPARISON OF MEASURED AND ESTIMATED STREET LOADS AT CONGRESS

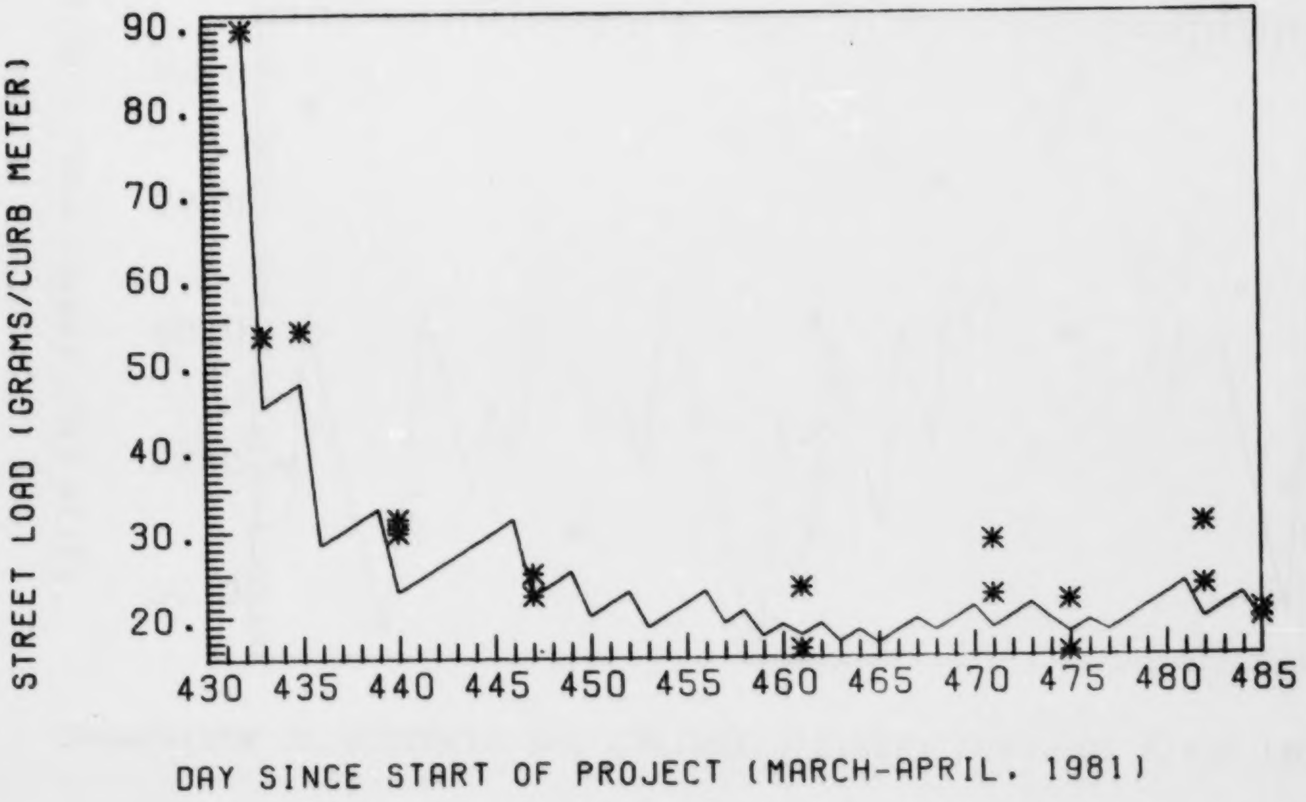
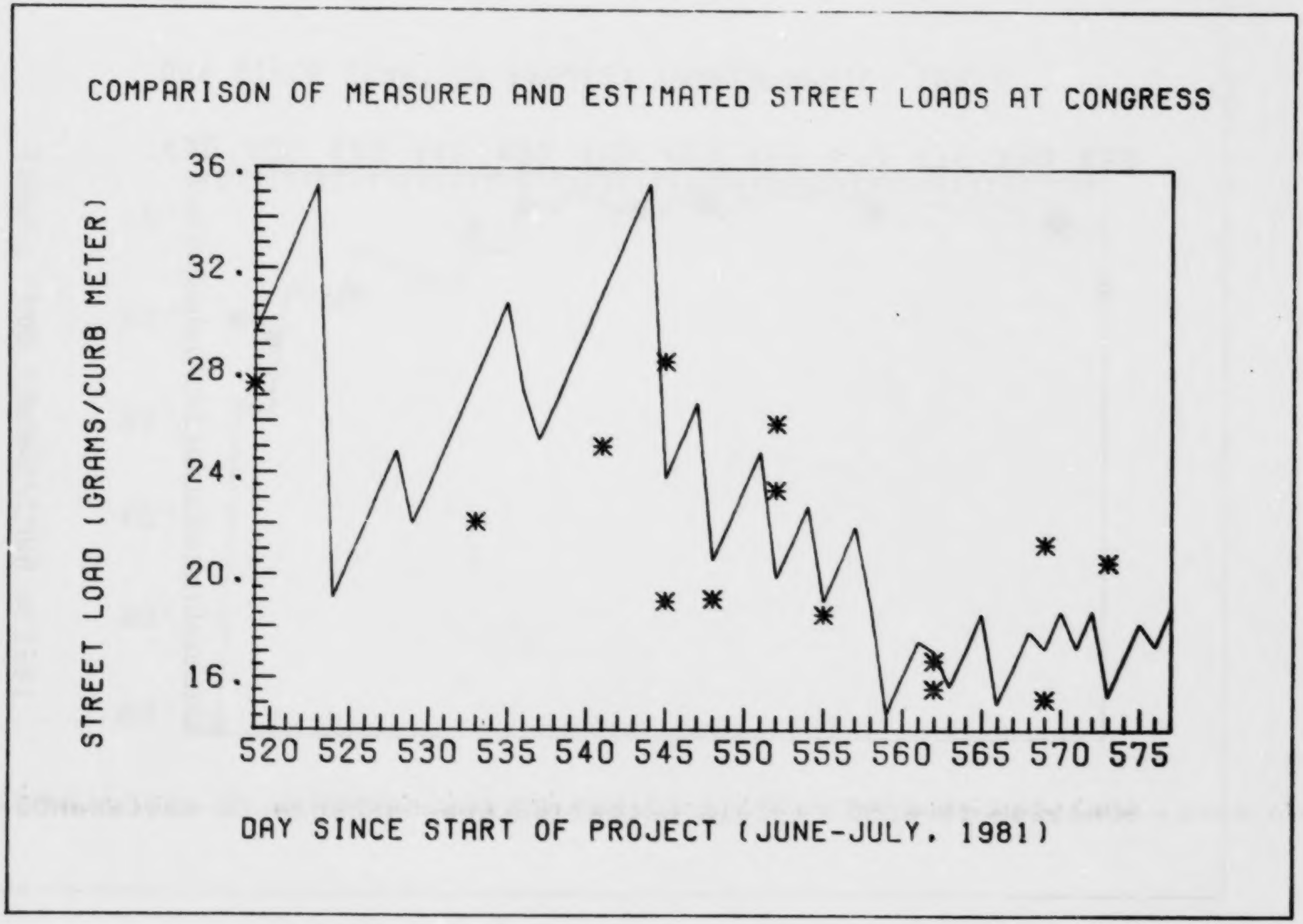


FIGURE IV.6



COMPARISON OF MEASURED AND ESTIMATED STREET LOADS AT CONGRESS

FIGURE IV.7

COMPARISON OF MEASURED AND ESTIMATED STREET LOADS AT HASTINGS

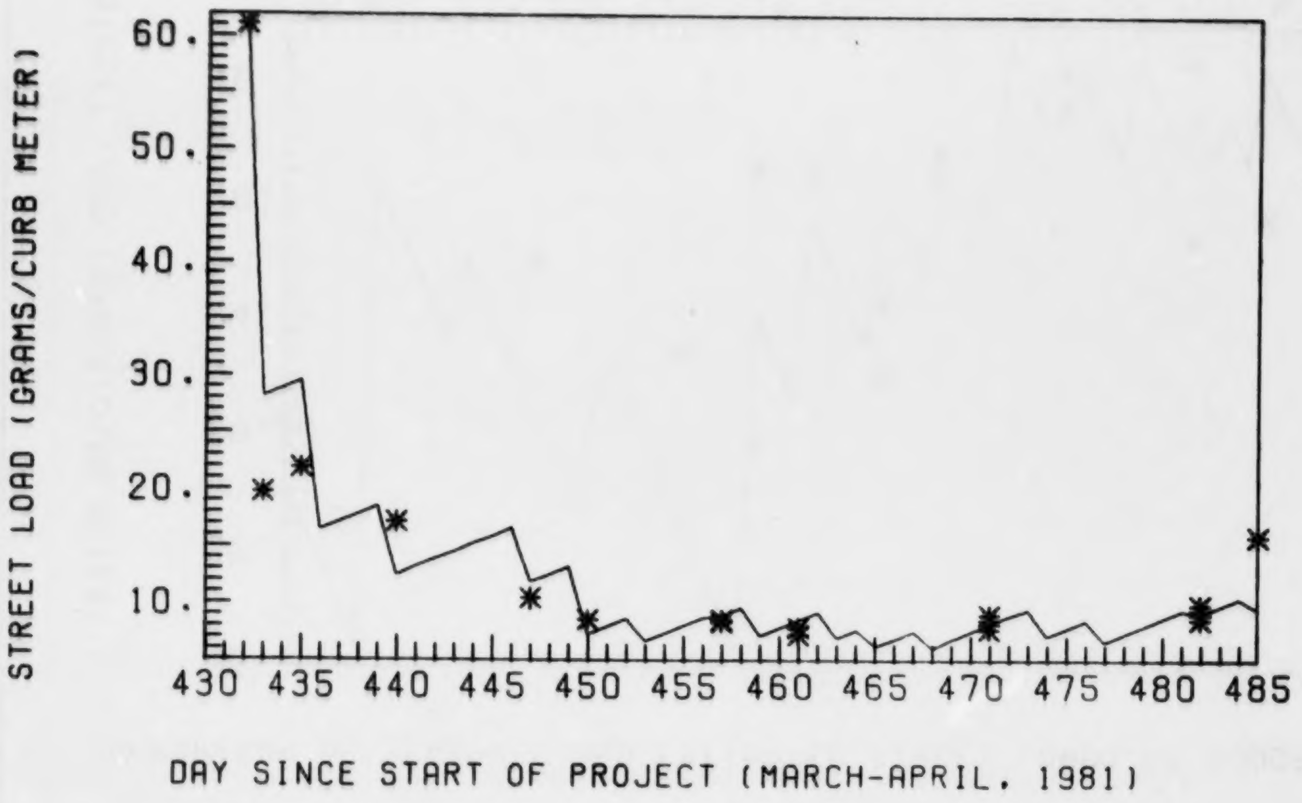
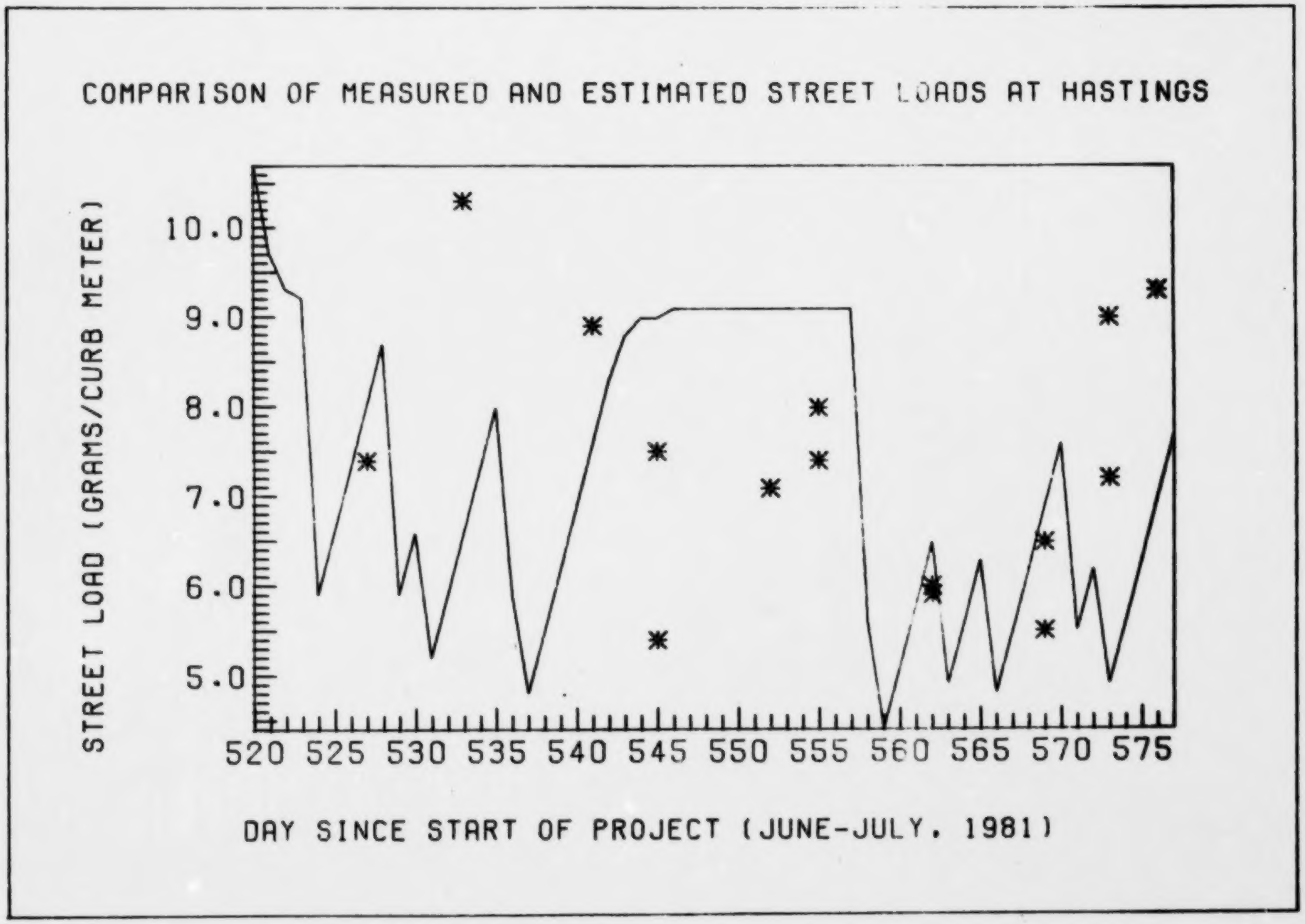


FIGURE IV.8



COMPARISON OF MEASURED AND ESTIMATED STREET LOADS AT HASTINGS

CHAPTER V
SAMPLING EFFORT

INTRODUCTION

This brief report section summarizes the sampling effort associated with the Milwaukee NURP project.

WATER QUALITY SAMPLING EFFORT

Monitoring of storm runoff, accumulated precipitation, and water quality was started at four sites in March 1980. Two additional sites were activated in June 1980 and the last two sites were activated in May 1981. At the end of the 1981 calendar year the rainfall amounts for 906 events had been measured at all of the stations. The criteria established for separating rainfall events is a period of three hours without any additional accumulation. A summary of the storm events shows the following:

Storm Event Precipitation		Percent of Storms
0.05"		35%
0.05" to 0.20"		24%
0.21" to 0.50"		18%
0.51" to 1.00"		15%
1.01" to 1.50"		4%
1.51" to 2.0"		2%
2.0" to 3.0"		1%
3.0"		1%
	TOTAL:	100%

Table V.1 lists the storm frequency data by site. Of the 906 total storms that occurred for all sites combined, there were 475 which had rain totals more than 0.1" that should have resulted in sufficient runoff to activate the water quality samplers. At all of the sites combined, 415 storm events were sampled during the project. An average of 8 subsamples per storm event were analyzed.

STREET SURFACE POLLUTANT SAMPLING EFFORT

Table V.2 presents a summary of the total number of street surface samples collected in 1980 and 1981. Ideally, samples were to have been collected at least twice per week at each test area. Because of the lengthy time involved in taking each sample, and because of the limitations imposed by wet street surfaces and by other sampling responsibilities, overall sampling was less frequent.

TABLE V.1

NUMBER AND PERCENT OF RAINFALL EVENTS WITHIN PRECIPITATION RANGES (INCHES)

Station	Less Than .05	.05 to 0.2	0.2 to 0.5	0.5 to 1.0	1.0 to 1.5	1.5 to 2.0	2.0 to 3.0	3.0 to 4.0	More Than 4.0	Total
State Fair	34(29*)	26(21)	30(25)	20(17)	7(5)	3(2)	0	1(1)	0	121
Wood Center	44(31)	30(22)	34(25)	21(15)	5(4)	3(2)	0	1(1)	0	138
Lincoln	31(46)	18(27)	7(10)	10(14)	0	1(1)	1(1)	0	0	68
Congress	16(34)	12(26)	9(19)	4(9)	4(9)	1(2)	0	1(2)	0	47
Rustler	37(33)	34(30)	15(31)	19(17)	4(4)	3(3)	0	1(1)	0	113
Post Office	49(33)	35(23)	28(19)	24(16)	7(5)	4(2)	1(1)	2(1)	0	150
Burbank	62(42)	31(21)	24(16)	25(17)	5(3)	0	1(1)	0	0	148
Hastings	54(45)	25(21)	18(14)	19(16)	3(2)	0	0	0	2(2)	121
All Stations	327(36)	211(24)	165(18)	142(15)	35(4)	15(2)	3(.3)	6(.7)	2(.2)	906

* Number in parenthesis is percent of total, rounded to the nearest whole number.

Table V.2
SUMMARY OF STREET SURFACE SAMPLES COLLECTED

Station	Accumulation**	After Sweeping**	Washoff	Total
Hastings	70	29	5	112
Congress	63	34	7	116
Rustler*	53	16	5	117
State Fair+	40	30	2	159
Greenfield Ave.+	25	15	0	40
Side Streets+	14	9	0	23
TOTAL SAMPLES	265	133	19	567

*Both Rustler Rough and Rustler Smooth

+Prior to June 1981, State Fair was sampled as one area. Beginning in June 1981, it was divided into two areas (Greenfield Avenue and Side Streets) which were sampled separately.

**These sample numbers do not include the 1982 effort.

ATMOSPHERIC DEPOSITION SAMPLING EFFORT

A total of 242 wet deposition samples were collected from 45 different events. Attempts were made to monitor all precipitation events where sufficient volumes were collected. These samples represent rain amounts ranging from about 0.1 inches to about five inches. Constituents analyzed included (in order of high to low priority), total solids, total lead, total phosphorus, soluble phosphorus, sulfates, nitrate plus nitrites, ammonia-N, soluble lead, pH, acidity, conductivity, suspended solids, chloride, chemical oxygen demand and a limited number of multi-elemental analyses for trace metals. Constituents were analyzed using a priority scheme which was dependent on rainfall amounts and the subsequent volume collected.

A total of 93 dry samples were collected and analyzed for the different constituents during the project. Priority analyses were not a factor due to a constant 400 ml wash volume used in removing the deposited material. Constituents analyzed included total solids, total lead, total phosphorus, sulfate and COD.

All analyses, with the exception of pH, conductivity, and acidity, were performed by the Wisconsin State Laboratory of Hygiene Water Chemistry Department.

ROOFTOP RUNOFF SAMPLING EFFORT

A total of 48 samples were collected from sloped roofs during 19 events in November of 1981 and March through June of 1982. Samples were analyzed for chlorides, total and suspended solids, total and soluble phosphorus, ammonia, nitrate plus nitrite, total and soluble lead, total zinc, cadmium, sulfate and COD.

CHAPTER VI
QUALITY ASSURANCE PROGRAM

INTRODUCTION

Quality assurance is required for both the individual Milwaukee project and for the Nationwide Urban Runoff Program. Procedures and techniques must be accurate so the results of the monitoring effort are meaningful. These local goals can be met by a variety of procedures, but some standardization is needed before the results from all individual NURP projects can be compared on a national basis. This section discusses the major quality assurance (QA) effort required and carried out by the Milwaukee project. It begins with references to NURP QA requirements and then discusses special tests that were conducted by WDNR. The WDNR quality assurance program was patterned after the NURP quality assurance requirements. The special tests included analyses of equipment washing procedures, potential contamination sources, and sampling effectiveness. These discussions are separated into subsections addressing QA for water quality monitoring, street surface particulate loading monitoring, atmospheric wet and dry deposition monitoring, and rooftop runoff monitoring.

Important aspects of QA are the specific sampling and analyses procedures which were discussed previously. These procedures included comprehensive efforts to "track" the samples during collection and processing. These sample routing procedures were also discussed previously.

EPA QUALITY ASSURANCE REQUIREMENTS

The data collection QA program for the NURP projects was discussed by Shelley (undated) and brief excerpts of that document are presented in the following paragraphs.

Data collection and analysis will form one of the most important information sources for the Nationwide Urban Runoff Program. The need for comparability, transferability, and nationwide assessment mandate the incorporation of QA by all NURP projects. Therefore, it is essential that the monitoring programs that produce these data be soundly based and that they incorporate Quality Assurance as an integral part of their structure. This is as necessary for problem assessment monitoring as it is for Best Management Practice (BMP) effectiveness monitoring. A rather thorough discussion of 208 monitoring requirements, methods, and costs is contained in Appendix D of the Areawide Assessment Procedures Manual (USEPA, 1976).

Quality Assurance Coordinator

Assignment of responsibility is essential in establishing a viable quality assurance (QA) program. Therefore, a QA control coordinator should be designated and given responsibility for the entire monitoring QA program. Although the level of effort expended by this person will be a direct function of the size of the overall monitoring program, where at all possible it should be considered a full-time position.

The coordinator should develop a training program to ensure a minimal level of proficiency. He must recognize variations in ability and provide training to ensure that professional skills are appropriate to the task. Training programs should be administered in order to develop that level of competence which is necessary to carry out assigned functions. Moreover, these programs should be carried out in full cooperation with USEPA regional analytical quality control coordinators.

The coordinator should establish basic requirements (equipment repair facilities, etc.) for operating a water quality laboratory. Laboratory facilities should provide an environment free from atmospheric contamination which can affect the desired analyses. The laboratory should be clean, air-conditioned and/or heated, and have a well-lighted work area. Safety features and other facilities consistent with good operating requirements should be provided.

Laboratory Quality Assurance

The Environmental Monitoring and Support Laboratory (EMSL) has prepared a handbook for analytical quality control that provides sufficient information to allow inauguration or reinforcement of a program that will emphasize early recognition, prevention, and correction of factors leading to breakdowns in the validity of data from water and wastewater laboratories.

A very important step is the establishment of the precision and accuracy of methods used in the particular analytical laboratory.

According to the handbook cited above, actual samples, not standards, should be used to determine the precision and accuracy of the methods. The resulting data should be compared with published interlaboratory precision/accuracy data to determine that the analyses are in control.

Specific requirements for laboratory QA include:

- That duplicate samples be run approximately 10 to 20 percent of the time to verify the reproducibility of the respective methods. Data should compare favorably with initially established precision data.
- That known amounts of standard material be added to samples on a 1-to-1 concentration basis to verify the ability of the method to measure the particular constituent under consideration. Again, approximately 10 to 20 percent of the time should be spent on this activity. The resulting data should compare favorably with the initially established accuracy data.

Field Quality Assurance

Quality assurance in the field is probably one of the most slighted aspects of any monitoring QA program. This is especially important since it is here that most errors and inconsistencies are found. All NURP QA programs should adequately address QA in the field. It is especially important that standardized routines be developed and reduced to writing to impart clear understanding to all involved and avoid miscommunication.

Control checks should be performed during the actual sample collection. These checks are used to determine the performance of the sample collection system. In general, the most common errors produced in monitoring are usually caused by improper sampling, poor preservation, or lack of adequate mixing during compositing and testing.

Equipment Calibration

When equipment is used in a monitoring program, it must be well maintained and calibrated if readings are to have validity and, therefore, such efforts form an important part of a quality control program. Unfortunately, in view of the wide number of equipment types and designs that might be employed, the only real guidance that can be offered is to follow the manufacturer's directions and specifications. The important thing is that calibration be performed in a systematic fashion and that the results of all calibrations and checks be recorded permanently. The use of equipment tags that indicate when the last calibration was performed and where details of the calibration can be found in the permanent record is helpful.

Automatic samplers should have all operating aspects checked out in the laboratory before being taken to the field. Equipment used in long-term installations should be checked out at least monthly and often weekly, depending upon design. Superficial checkout and maintenance should be performed whenever samples are collected. For constant aliquot volume type composites, aliquot volume should be verified in the field after installation. Sampling equipment should be recalibrated immediately after use in the field.

Flow-measuring devices should be calibrated immediately before and after use in the field. The frequency of developing full range calibration curves will depend upon the type of device involved. At least three spot checks (one in the lower quarter of range, one near midrange, and one in the upper quarter of range) are usually required to verify a calibration curve established earlier and for large, fixed flow measurement stations.

Sample Preservation and Handling

Having collected a representative sample in question, there remains the problem of sample preservation and analysis. It is a practical impossibility either to perform instant analyses of the sample on the spot or to completely and unequivocally preserve it for subsequent examination. Preservative techniques can only retard the chemical and biological changes that inevitably continue following extraction of the sample from its parent source. In the former case, changes occur that are a function of the physical conditions. As examples, metal cations may precipitate as hydroxides or form complexes with other constituents, cations or anions may change valence states under certain reducing or oxidizing conditions, constituents may dissolve or volatize with time, etc. Biological changes may change the valence state of an element or radical; soluble constituents may be converted to organically bound materials in cell structures, cell analysis may result in release of cellular material into solution, etc.

Preservation methods are relatively limited and are generally intended to retard biological action, retard hydrolysis of chemical compounds and complexes, and reduce volatility of constituents. They are generally limited to pH control, chemical addition, refrigeration, and freezing. EMSL in its Methods for Chemical Analysis of Water and Waste (USEPA, 1974) has compiled a list of recommendations for preservation of samples according to the measurement analysis to be performed.

Proper sample handling is also essential to successful results from any monitoring program. Great pains taken in all other areas may be for nought if samples are accidentally exchanged or otherwise misidentified. The same sample identification system obviously would not be suitable for all types of monitoring programs all across the country, but every program must have one, and it should be thoroughly understood by all involved.

Chain Of Custody Procedures

Although strict Chain of Custody procedures will in all likelihood not be warranted for most NURP projects, the procedures developed by the USEPA should be thoroughly reviewed and used as a framework for developing sample handling procedures for each project. Recommended Chain of Custody procedures are presented in the USEPA NPDES Compliance Sampling Inspection Manual (USEPA, 1977).

Sampling Equipment Cleaning

The proper cleaning of all equipment used in the sampling of water and wastewater is essential to ensuring valid results from laboratory analyses. Cleaning protocols should be developed for all sampling equipment early in the design of the monitoring program. Here, also, the laboratory analyst should be consulted, both to ensure that the procedures and techniques are adequate as well as to avoid including practices that are not warranted in view of the analyses to be performed.

STORMWATER SAMPLING QUALITY ASSURANCE PROGRAM

The quality assurance program for the stormwater runoff portion of the Milwaukee NURP study included washing and maintenance of samplers, bottles, and processing equipment. Also included was an intensive sampling program to verify the efficiency of the washing procedures in removing contaminants. Blank samples were obtained from the samplers, splitter, bottles, and filtration apparatus and analyzed for a variety of potential contaminants. Appendix B is the memo that the laboratory personnel followed to obtain these blanks. The following paragraphs discuss these topics.

Cone Splitter

The USGS DECA "cone splitter" was used to split the stormwater samples into several well-mixed, equal aliquots for laboratory analysis (see Chapter III). Before each use, the splitter was disassembled and cleaned with a brush using a QED-II nonphosphorus soap solution. It was then rinsed three times with tap water and three times with distilled water. The splitter was also rinsed between event samples with distilled water to prevent cross-contamination. Approximately once each month, a liter of distilled-deionized water was passed through the splitter following routine sample processing procedures and analyzed for total and soluble phosphorus, chlorine, total and suspended solids, nitrite-nitrate, ammonia, and total lead.

Filtering Apparatus

A 0.45 um Millipore membrane filter was used to vacuum filter samples in preparation for soluble phosphorus and soluble lead analyses. The filtration apparatus was cleaned with a 50% HCl rinse and three rinses with distilled water before each day's use. Between each sample it was cleaned with 10% HCl and rinsed three times with distilled water, again, to prevent cross-contamination of samples. Distilled water blanks were run through the filter before and after the stormwater samples were processed. These distilled water blanks were then analyzed for soluble phosphorus. Almost all of the samples (92.8% or 116 of 125) of the values were less than 0.004 mg/l soluble phosphorus. The filtration apparatus cleaning procedure was successful in removing unwanted soluble phosphorus.

Sample Bottles

The bottles used in the Manning S-4050 automatic water samplers were washed after each precipitation event with a power spray washer (E.L. Mattson model #MB-1500) which delivered three gallons per minute at a pressure of 500 psi. The bottles were first sprayed with a soap solution (QED-II nonphosphorus detergent), followed by a tap water rinse, and finally be a distilled water rinse. The spray washer was essential because the one liter bottles were wedge-shaped with corners inaccessible to brush-cleaning. The bottle caps were hand-washed using the same cleaning procedure. Approximately three percent of the dry, washed bottles were sent to the Wis. State Lab of Hygiene, where distilled water was added and analyzed for total and soluble phosphorus, total solids, nitrite plus nitrate-N, ammonia, and total lead. All total phosphorus (37 total) and 98.5% (67 of 68) soluble phosphorus blanks were less than the normal detection limit of 0.004 mg/l. Ammonia and nitrite plus nitrate blanks (68 each) were all less than the detection limit of 0.02 mg/l. Thus, given the numerous blanks analyzed, the bottle-washing procedure successfully controlled this potential contamination. More than one-half (57.3% or 39 of 68) of the total lead blanks were less than the 3 ug/l detection limit. Almost all (88.2% or 60 of 68) were less than or equal to 10 ug/l lead. The highest level was 36 ug/l lead. The higher values were evenly distributed over the entire sampling period and cannot be attributed to one poor washing.

Automatic Samplers

The automatic samplers (Manning model S-4050) and intake sample hoses used were routinely rinsed with distilled water after each runoff event (usually within 24 hours). Also, the Manning sample chambers (a plastic cylinder on the sampler used to measure and collect the volume of sample before delivery to the sample bottles) were dismantled, scrubbed, and rinsed with distilled water every 5 weeks to remove any accumulated solids deposits. Approximately once per month, a liter of distilled and deionized water was passed through the sampler using the manual sampler activation mode. The collected water was then analyzed for total and soluble phosphorus, total and suspended solids, nitrite plus nitrate-N, ammonia, and total lead.

Many of the total phosphorus blanks (61.5% or 16 of 26) were less than or equal to 0.004 mg/l. Most (88.5%) were less than or equal to 0.005 mg/l phosphorus. There were also 16 other blanks that were analyzed at detection limits of 0.01 mg/l and 0.02 mg/l phosphorus and are not included in the above statistics.

Almost all (96.7% or 29 of 30) soluble phosphorus blanks were less than or equal to 0.004 mg/l, and 46.7% were as low as 0.001 mg/l. The difference between the soluble and total phosphorus values suggest the presence of contaminating solids.

Nitrite plus nitrate levels are all (35 total) less than or equal to the detection limit of 0.02 mg/l. Many (68.6% or 24 of 35) of the ammonia values were less than or equal to 0.02 mg/l, and 91.4% (32 of 35) were less than or equal to 0.04 mg/l.

Almost all of the chlorides blanks (90.6% or 29 of 32) were below the 2 mg/l detection limit.

Most (80.6% or 32 of 40) of the total lead blank values were less than or equal to 3 ug/l. The two highest values were from the samplers at Wood Center (38 ug/l) and State Fair (29 ug/l) and both blank samples were obtained on the same day (December 10, 1980).

Results and Discussion

To evaluate the success of the quality assurance water quality program, the blank QA sample concentrations were compared with the median stormwater sample concentrations. Table VI.1 shows the QA blank medians and the probability of an event mean concentration being lower than this median. The QA medians and probabilities are presented for samplers, bottles, splitter, filter, and combined medians. The medians represent "worst case" conditions because all "less than" concentrations (below detection limits) are expressed at the highest possible number (i.e., < 0.004 is expressed as 0.004). The combined median is the sum of the sampler, bottle, splitter, and filter medians, making the assumption that the contamination is additive (which is not likely true). In a few instances, unusually high detection limits were used by the laboratory, and these values were not used.

The median soluble phosphorus concentrations of the filtration blanks was 0.001 mg/l. The probability that this concentration could exceed the event mean concentration (EMC) is only 0.01%. Of the blanks analyzed, 93.1% had concentrations below the detection limit of 0.004 mg/l.

The splitter blank median concentrations were also very low. Total solids blanks had a median of 5.0 mg/l and had less than a 0.01% chance of exceeding the EMC. Volatile suspended solids, suspended solids, total and soluble phosphorus, nitrite plus nitrate, and total lead also had less than a 0.01% chance of exceeding the EMC. The only two constituents to exceed this probability were ammonia (0.51%) and chlorides (8.23%). Ammonia, which had a 0.51% chance of exceeding the EMC (median, 0.05 mg/l), was still very low, but the concentrations may be higher because the splitter was rinsed with distilled water only (not distilled-deionized). Chlorides appear quite high

TABLE VI.1
STORMWATER QUALITY ASSURANCE MEDIANS AND THE PROBABILITY OF AN EVENT MEAN CONCENTRATION BEING LESS THAN THE Q.A. MEDIAN

Pollutant (mg/l)	Samplers	Bottles	Splitter	Filtration	Combined Medians
Total Solids	10 (0.0001)*	id	5 (0.0001)	id	15 (0.001)
Vol. Sus. Solids	0 (0)	id	0 (0)	id	0 (0)
Sus. Solids	1 (0.0001)	id	1 (0.0001)	id	2 (0.0008)
Total Phosphorus	0.005 (0.0001)	0.002 (0.0001)	0.004 (0.0001)	id	0.011 (0.0003)
Sol. Phosphorus	0.002 (0.0007)	0.001 (0.0001)	0.001 (0.0001)	0.001 (0.0001)	0.005 (0.0116)
Ammonia	0.02 (0.0001)	0.01 (0.0001)	0.05 (0.0051)	id	0.08 (0.026)
Nitrite plus Nitrate-N	0.02 (0.0001)	0.01 (0.0001)	0.015 (0.001)	id	0.045 (0.0015)
Total Lead	0.003 (0.0001)	0.003 (0.001)	0.003 (0.001)	id	0.009 (0.0015)
Chloride	2.0 (0.0823)	id	2.0 (0.0823)	id	4.0 (0.18)

* ( ) is probability value

id insufficient data

relative to the event sample mean because of the high detection limit of 2 ug/l when compared to the EMC. Eight of the nine total chloride blanks were below the 2 mg/l detection limit, but were considered as 2 mg/l in this analysis.

Bottle-washing blanks had extremely low concentrations, with all median concentrations having less than a 0.01% chance of exceeding the event means. Almost all (99%) of the soluble phosphorus blanks (96 of 97) were below 0.004 mg/l. All 95 ammonia and nitrite plus nitrate samples were 0.02 mg/l. Most (81.4% or 79 of 97) of the total lead samples were 6 ug/l. The highest total lead value was 36 ug/l (5.71% chance of exceeding the EMC).

Total lead contamination was a problem with the bottle-washing blanks. The distilled water used to rinse the bottles was tested and, in all eight samples, was always less than the detection limits (3 ug/l). The problem was probably associated with incomplete washing, especially of the smaller solids which would be difficult to rinse from the oddly shaped bottles.

The automatic samplers represented the greatest potential source of contamination due to components which were inaccessible to routine brush-cleaning methods (i.e., purge chamber and connecting hoses). Despite this potential problem, the sampler blanks indicated successful removal of most contaminates. All constituent median concentrations, except chloride and soluble phosphorus, had 0.01% probabilities of being larger than the EMC values. Soluble phosphorus, with a median blank concentration of only 0.002 mg/l, had 0.07% chance of exceeding the EMC. The highest soluble phosphorus blank concentration was 0.007 mg/l which had a 2.6% probability of exceeding the EMC. The chloride median concentration was 2 mg/l and had a 8.23% chance of exceeding the EMC. As previously stated, the chloride detection limit was 2 mg/l. Most (30 of 33) chloride blanks were below the detection limit of 2 mg/l, but were calculated as 2 mg/l, artifically elevating the probability of exceeding the EMC. There was some concern about the sampler blanks with respect to total lead, ammonia, total solids and suspended solids. These levels were not extremely high, but could be decreased, possibly by increasing the frequency of cleaning. The higher levels found were spotty and inconsistent. Samplers were flushed with distilled water after each rain event. The sample chambers were scrubbed monthly with QED-II detergent and rinsed with distilled water. There are many parts of the sampler which could not be scrubbed. The high concentrations of solids in the runoff could have also caused higher blank concentrations than desired.

The sum of the quality assurance blank concentration medians represents the "worst case" (combined) contamination effect. Although these medians would not be additive, they are shown as a worst case condition. All the constituents, except for soluble phosphorus, ammonia, and chlorides had a probability of 1.0% in exceeding the EMC. Soluble phosphorus and ammonia medians had just slightly increased probabilities, at 1.2% and 2.6%, respectively. Chloride has a combined median of 4.0 mg/l and a 18% probability of exceeding the EMC. It must again be emphasized that the samples are nearly all below the 2 mg/l detection limit and this probability value is therefore too high.

In general, all of the blank analyses indicate that the QA program for stormwater runoff sampling procedures was successful in removing potential interferences which could potentially bias data interpretation. In most cases, the QA medians had a very low probability of exceeding the event mean concentration. Most blanks for all constituents were less than the laboratory detection limits, so these probability values are higher than expected. The more probable effect of significant interferences, such as increasing the EMC values by ten or 25%, is greater than the values discussed previously. The probabilities of these more frequent, but significant interferences, are probably mostly less than ten percent.

STREET SAMPLING QUALITY ASSURANCE

The quality control aspects of the street surface particulate monitoring program included vacuum velocity tests, sampling method difference tests between two NURP project procedures, sampling effectiveness of dry verses wet sample collection, routine replacement of vacuum nozzles, and nozzle-wear tests. The special tests discussed in this section were conducted in response to these potential problems. The results of these tests quantify these potential sampling errors and were considered in evaluating the project data.

Quality assurance aspects of the street surface particulate sampling efforts mainly involved the experimental design considerations discussed previously (how many samples need to be collected, etc.) and the other special tests considered in this discussion. Other very important aspects of quality assurance include the sample processing, laboratory tracking, and analytical procedures, also discussed previously.

Collecting Street Surface Particulate Samples Random Grids

Random sampling using a random number grid has been found to be impractical for street surface particulate sampling. Problems include parked cars and the extra sampling time required. Maps of the streets in the watershed were used to determine the total length of the streets. The number of subsamples necessary (previously discussed in Chapter III) was then divided into the total street length to obtain the approximate subsample interval. This yielded a representative distribution of subsamples throughout the watershed, which were independent of any specific street or adjacent area conditions.

In areas of heavy parking (i.e., West Allis), the proportion of each street length to the total area street length was determined and each street was assigned a specific number of subsamples needed. Despite the parked car densities, the required number of subsamples were then obtained from each particular street. This sometimes resulted in two subsamples being taken close together. In the case of Greenfield Avenue (West Allis), many of the subsamples were obtained in areas designated as bus-stops because of parking problems.

The parking lot (Capitol Court) subsampling design was unique because the site was divided into two separate areas. There were a large number of subsamples in each area (30 in the "smooth" area and 32 in the "rough" area). Time and parking problems did not allow for 62 individual stops. Three subsamples were therefore taken at each stop, for a total of 20 sampling stops for the entire watershed. The sampling stops were chosen to be visually representative of existing conditions within the limits of the available area.

Comparison of D & B Street Sweeper and West Allis Street Sweeper

An experiment was conducted with the cooperation of the D & B Industrial Cleaning Company and the City of West Allis to compare the removal rates of the private sweeper used for the Milwaukee NURP street-sweeping program, and a newer sweeper used by the City of West Allis. Both sweepers were of the three-wheel mechanical brush and conveyor type. All streets selected for this test were located in the City of West Allis. Boulevard curbs were swept rather than outer curbs, as they were more uniform in their distribution of accumulated material and less influenced by sidewalks, parked cars, trees, and businesses or industries located on the streets.

The sweepers simultaneously swept each side of a predetermined length (180 meters) of the boulevard. Sweeping procedures, such as speed (3 to 4 mph) and spray bar water application were standardized as much as possible. The sweepers started each test with a clean hopper. After sweeping each 180 meter section, the hoppers were emptied and carefully cleaned using a broom and/or squeegee. Finally, the samples were dried in an oven at 105°C for 24 hours or until they reached a constant weight.

The samples were taken from five different boulevard sections on two days, August 2, 1982 and August 30, 1982. Thus each section was sampled twice, once each day. Test results are shown on Table VI.2. The particulate loadings removed varied from about 1 to 13 grams/curb-meter.

Conditions beyond the tests' control, such as brush length and quantity of accumulated material, varied for the two sampling days and street sweepers. Perhaps the most significant change was the inside (left) gutter broom length on the West Allis sweeper. On August 2, the length was 7.0 inches and on August 30, was 8.5 inches. The measurements for the D & B sweeper were 8.5 inches on August 2 and 8.0 inches on August 30. It was visibly evident on August 2 that the West Allis sweeper was leaving a thin line of material adjacent to the curb, while the D & B sweeper was not. This may explain the lower removal rate for the West Allis sweeper on August 2. The average weight of the hopper material for the D & B sweeper on August 2 was 1310 grams versus 691 grams for the West Allis sweeper; nearly a two-fold difference. On August 30 the average weights were much closer, with the D & B hopper material weight at 1334 grams and West Allis hopper material weight at 1,461 grams.

Several statistical tests, including the nonparametric Wilcoxan Signed Rank Test, were performed on the data to determine whether one sweeper was picking up significantly more material than the other sweeper. The results indicated, on the basis of all ten samples, that there is no reason to believe that one sweeper picked up more material than the other (alpha = 0.432, or a probability of a difference of 57%). If the samples are separated by sampling day before statistical analyses, a possible significant difference was noted. On August 2, using the Wilcoxan Signed Rank Test, it can be said with about 91% confidence (H_0:u=no difference vs H_a:u 0, alpha = 0.094) that the D & B sweeper picked up more material. On August 30, the West Allis sweeper picked up more material at the much lower confidence level of 78%.

TABLE VI.2
DRIED HOPPER WEIGHTS (g)*

Date	Sample No.	West Allis	D & B	West Allis Minus D & B
8/2/82	1	326	778	-452
"	2	325	611	-286
"	3	587	1534	-947
"	4	819	2549	-1730
"	5	1396	1080	+316
Subaverage		691	1310	-620
8/30/82	6	1483	541	+942
"	7	898	661	+237
"	8	1620	1510	+110
"	9	1794	1568	+226
"	10	1508	2390	-882
Subaverage		1461	1334	126
TOTAL		10,756	13,220	-2,466
AVERAGE		1,076	1,322	-247

*Includes container weight: approx. 158 g.

The differences observed on August 2 may be related to the ability of the longer curb brush on the D & B sweeper to scour the area adjacent to the curb.

Hopper Weight and Street Surface Sampling

Street sweeper hopper samples were collected with corresponding "before" and "after-swept" vacuum samples four times to evaluate how well the "before" and "after" sampling procedures corresponded to the street cleaner hopper material weight. The most accurate measure of the material a street sweeper has removed from the street is obtained by weighing its hopper contents, assuming the hopper and sweeper elevator can be completely cleaned. This weight can be converted to a curb-length removal rate by dividing the hopper weight by the number of curb-meters that the street cleaner operated.

The "before" and "after-swept" street dirt samples were taken immediately before and after the sweeper passed through the test watershed. The samples were representative of the material in the streets before and after sweeping, based on the experimental design tests. Their difference in weight, therefore, represents the street sweeper's removal rate.

The street sweeper started cleaning each watershed with a clean hopper and, upon completion of the test, the hopper was emptied onto the street and was brushed out with a broom. The hopper material was air-dried until no moisture was visible and weighed in large containers suspended from a spring scale. Vacuum samples were collected immediately before and after the watershed was swept, using routine street monitoring methods. These samples were sent to the U.S.G.S. laboratory in Madison, Wisconsin to be weighed and processed.

Table VI.3
COMPARISON OF VACUUM SAMPLING VS. HOPPER WEIGHT REMOVAL RATES*

		VACUUM SAMPLING		HOPPER WEIGHT	
Station	Date	Before-Sweep	After-Sweep	Before-After Removal Rate	Sweeper Removal Rate
Congress	5/3/82	38.6	28.7	9.9	16.5
Congress	6/14/82	29.4	18.5	10.9	23.8
Hastings	5/18/82	17.2	22.8	5.6	22.8
Rustler	6/10/82	15.4	10.1	1.3	6.8

*grams/curb-meter, except for Rustler, which is grams/M^2

Results of these tests are shown in Table VI.3. They indicate large differences between removal rates based on the before minus the after-swept vacuum samples and the hopper measurements. The hopper weights were always greater than the street loading differences.

The discrepancy between the hopper weight data and the vacuum sample data is difficult to interpret. An important reason for the higher hopper weights is that the hopper samples were probably not as dry as the vacuum samples when weighed. The hopper samples were air-dried because of their large volume and may have had enough moisture remaining to account for the difference. Samples of the hopper material should have been analyzed for moisture content and particle size distribution. The hopper also included many more rocks, cans, litter, tree branches, etc., that was not included in the street dirt samples.

In Pitt's San Jose Study (1979), street cleaner hopper material was much wetter than street dirt samples because of the use of the dust controlling spray bar on the street cleaner. The street dirt samples usually had less than one percent moisture, as collected, while the hopper material usually had more than ten times this moisture content (30 to 40 percent moisture was not unusual for the hopper material). The hopper material was also very difficult to dry (due to its high organic content), usually requiring several days in a drying oven.

The purpose of these street dirt measurements was to determine the effects of street cleaning on the street loading values (and their washoff potential). Loading value changes may be indicative of the amount removed by the street cleaners, but, as noted in these tests, other mechanisms may reduce the correlation between the two measurement methods.

Lead Contamination Due to Vacuum Nozzle Wear

The vacuum nozzles used with the street surface monitoring equipment wear rapidly as a result of abrasion with the street surfaces. The nozzles are 6 inches (15.2 cm) wide when new and are replaced when wear reduces them to approximately 5 inches (12.7 cm) after 3 to 4 weeks of sampling. This procedure helps to maintain relatively constant vacuum suction characteristics and sampling widths.

Special tests were conducted to evaluate the potential for this nozzle wear material to contaminate the samples. A sample of vacuum nozzle filings was analyzed for total lead (Pb) and was found to contain about 400 ug of lead per gram of filings. The mass of a vacuum nozzle was determined before and after a typical sampling period at the Hastings, W. Congress, and 77th Street watersheds. These losses in nozzle weight were as follows:

Loss at Hastings after 27 subsamples = 2.12 g
Loss at W. Congress after 24 subsamples = 0.99 g
Loss at 77th Street after 25 subsamples = 0.92 g

If, as a "worst case", it is assumed that 100% of the vacuum nozzle wear is taken in as part of the sample, then the contamination of lead per sample would be:

Hastings: 2.12 g lost x 0.4 mg/g = 0.85 mg of lead
W. Congress: 0.99 g lost x 0.4 mg/g = 0.40 mg of lead
77th STreet: 0.92 g lost x 0.4 mg/g = 0.37 mg of lead

Table VI.4 shows the results of these calculations. Even in a "worst case" condition, the amount of lead lost from the vacuum nozzle during normal wear was not enough to significantly alter the measured lead loadings.

Fine Sample Loss During Sample Transfer

An uncertain amount of very fine dust is lost from each sample during sample handling. This is due to wind and adherence to the containers. Wind has the obvious effect of blowing fine dust particles out of the vacuum canister while removing the sample. The finer particles suspend quite readily. Adherence of the sample to vacuum filters, canisters, sample containers, and brushes is also a potential source of losses.

All of these losses affect the smallest (50 microns) particle sizes more than the large particle sizes. Practices to reduce wind losses (such as using vacuum bag inserts) typically result in greater sample losses by penetration losses in the bag fabric. These small particle sizes are a very small fraction of the total sample weight (usually only a few percent). Therefore, even substantial losses of these fines would have very little effect on the total sample weight. Obviously, loadings of the smallest particle sizes are subject to this greater error, and care must be taken in analyzing these loadings.

Effects of Equipment Configurations on Vacuum Sampler Intake Velocities

The two equipment variables most affecting sampling effectiveness are vacuum sampler intake velocity and suction. Special tests were conducted to determine how different vacuum sampler configurations affect intake velocity.

On July 2, 1982, a quality assurance test was conducted to determine vacuum velocity of the present Milwaukee NURP street particulate monitoring equipment and other possible equipment arrangements.

Velocity tests were performed on the NURP vacuum system using an ALNOR Thermo-Anemometer installed within a four inch diameter velocity reducer. The four inch attachment was secured to the end of a twenty-five foot 1-1/2" diameter vacuum hose normally utilized during street contaminant sampling. The attachment was necessary for velocity reduction as the anemometer used did not cover the velocity range found within the 1-1/2" hose (i.e. off scale readings). Velocity within the 1-1/2" hose was then calculated using the formula:

$$AV = Q \text{ or } \frac{Q}{A} = V$$

where: A = x-sectional area in sq. ft.,
V = velocity in ft. per minute, and
Q = flow in cu. ft. per minute.

Approximately 72 percent of the tandem vacuum velocity was attained by using one single vacuum unit (see Table VI.5). The average tandem velocity was 128 fps verses 92 fps using a single vacuum unit.

TABLE VI.4
MAXIMUM POTENTIAL VACUUM NOZZLE LEAD CONTAMINATION TO SAMPLES

Study Area	Typical Street Dirt Loading (g/curb-meter)	Typical Lead Street Loading (mg/curb-meter)	Contamination Loadings (mg/curb-meter)	Contamination/ Per Sample (%)
Hastings	15	300	0.10	0.034
Congress	35	480	0.055	0.015
State Fair	90	1,950	0.050	0.025

TABLE VI.5
VELOCITY AND VOLUME TEST RESULTS; TANDEM VS. SINGLE VACUUM UNIT ARRANGEMENTS

	Ft/Min.	Ft/Sec.	Ft^3/Sec.
		Tandem Hose	
	7,975	133	96
	8,333	139	100
	7,608	127	91
	7,250	121	87
	7,250	121	87
Average:	7,683	128	92
		Single Hose	
	6,167	103	74
	5,417	90	65
	5,417	90	65
	5,417	90	65
	5,417	90	65
Average:	5,542	92	66

Neither single or tandem vacuum arrangements attained the maximum cfm rating as listed by the manufacturer (110 cfm per vacuum). This is probably due to friction losses within the 25 foot hose, the age of the motors, and small particles that tend to clog the two filter components. Hose and fitting leaks would also reduce the flow rate.

Champaign and Milwaukee Sampling Effectiveness Tests

On March 9-10, 1981 an experiment was conducted to determine the differences between two NURP street dirt monitoring systems, one used in Milwaukee, WI and the other used in Champaign, IL. Three different watersheds were vacuum sampled using the same subsample location and times in Milwaukee. The variables tested were equipment and operator technique.

The vacuum canisters were emptied into plastic bags after the entire watersheds were sampled. Samples were then returned to the Southeast District DNR lab and processed by weighing on an analytical balance after sample drying. Tests were also conducted comparing wet and dry sample collection efficiencies.

The Milwaukee sampling equipment consisted of two industrial vacuums (Milwaukee Model #8925 stainless steel vacuum units, 15 gallon capacity, 110 cu. ft. per/min. minimum air flow, 10 amps.) that were joined with a Y-connector and used a 1-1/2 inch diameter hose, 25 feet long. A stainless steel double-bend wand, and 6" wide alloy vacuum nozzle were also used. The Champaign sampling equipment consisted of a single industrial vacuum (Hild Model #730 stainless steel vacuum unit, 30 gallon capacity, 2.3 horsepower motor) and a two inch, 20 foot hose with an aluminum wand and a five inch triangular nozzle. The Champaign equipment delivered less air velocity at a lower vacuum suction and had to be removed from the sampling vehicle for each subsampling.

Results shown on Table VI.6 indicate a consistent increased removal rate for the Milwaukee NURP sampling equipment. The ratio of Milwaukee to champaign removal weights ranged from 1.07 to 1.77 and averaged about 1.31.

Table VI.7 shows the sampling effectiveness differences for these two sampling procedures on a particle size basis. When the results were compared using a two-tailed Students "T" test, significant differences at the 90% level (alpha 0.1) were only noted for the particle sizes less than 250 microns. Therefore, the increased sampling efficiency of the Milwaukee equipment is most important for the smallest particle sizes. There were much smaller differences observed for the larger particle sizes. There are fewer of these smaller particles in a typical street dirt mixture, but the concentrations of many pollutants on the particles are greater than for the more abundant larger particles. The observed differences in total sample loadings, as shown on Table VI.6, will make it difficult to compare the Illinois loading observations with loadings obtained using more powerful sampling equipment.

Sampling effectiveness was also measured by first dry vacuuming a small area (about ten feet long to the street centerline) using the standard sampling equipment. The same area was then dry sampled a second time and finally

TABLE VI.6
COMPARISON OF MILWAUKEE AND CHAMPAIGN STREET SURFACE SAMPLE METHODS

Watershed	No. of Subsamples	Sample Weight (g) Milwaukee	Champaign	Mass Difference	Milwaukee to Champaign Ratio
Hastings	24	146.3	160.9	14.6	0.91
"	24	173.0	119.0	54.0	1.15
"	27	139.3	122.9	16.4	1.13
Subtotal	75	458.6	402.8	55.8	1.14
State Fair	20	1,173.8	954.6	219.2	1.23
Congress	24	398.5	245.9	152.7	1.62
"	24	342.2	318.8	23.4	1.07
"	27	517.3	292.9	222.4	1.77
Subtotal	75	1,258.0	857.6	407.7	1.47
TOTALS	170	2,890.4	2,215.0	675.4	1.31

TABLE VI.7
COMPARISON OF MILWAUKEE AND CHAMPAIGN NURP STREET SURFACE VACUUM SAMPLERS

	Average Sample Weight (g)			
Particle Size (mm)	Wisconsin	Illinois	Wisconsin Minus Illinois Values	Alpha*
0.63 - 0.125	30.27(15.8)**	18.70(9.3)	11.56(9.2)	.03
0.125 - 0.25	38.27(21.1)	28.10(13.1)	10.17(11.4)	.08
0.25 - 0.5	48.45(27.6)	38.73(16.2)	9.72(15.8)	.19
0.5 - 1.0	30.50(16.2)	26.23(9.02)	4.27(9.8)	.34
1.0 - 2.0	22.87(12.7)	20.78(9.7)	2.08(4.7)	.33
2.0 - 4.0	19.08(13.2)	19.37(11.5)	-.28(8.1)	.93

*Alpha is the attained level of significance of a two tailed t test that the means of the difference of Wisconsin-Illinois sample loading values is equal to zero, vs. the mean is not equal to zero.

**The numbers in parenthese are standard deviations.

flushed with water, with this runoff collected using a wet vacuum. The loads removed by the two dry and one wet vacuuming were then determined by sample drying and weighing. Table VI.8 shows the results of these tests, on a particle size basis. The removal effectiveness was greatest for the large particles on the smoother concrete streets (about 90% removal). The overall removal by the standard dry sampling procedures was about 85% for the concrete streets and about 55% for the rougher asphalt streets. the first and third samples were collected using the Milwaukee dry sampling equipment first, followed by the Champaign dry sampling equipment, and finally the flushing and wet vacuuming. the second and fourth samples were collected by the Champaign dry sampler first, followed by the Milwaukee sampler and finally by the same flushing and wet vacuuming. The street textures (smoother concrete verses asphalt) were much more important in determining sampling effectiveness than the choice of samplers.

These tests indicated the amount of street dirt that was removed from the street after the normal single pass sample collection procedure. As Pitt has stated in his Bellevue NURP report (1983), this is not an indication of how much more material would washoff the street during rain events when compared with the street sampling. Very few rain events would be as effective in cleaning the street as the spraying and wet-vacuuming procedures used in these tests. These tests were mainly used to confirm that the single pass dry vacuum procedures removed more material than the rain events and the mechanical street cleaning equipment.

Pitt's (1983) sampler effectiveness tests were conducted in a similar manner for a variety of street loading and moisture conditions. He found that the first dry vacuum sample collected about 40 to 85 percent of the total absolute street surface load. The percent recovery was better for smooth streets having higher street surface loads and somewhat less for more damp street surfaces, or rougher streets. The sample recovery with the first dry vacuum pass was much greater for the larger particle sizes than for the smaller particle sizes as was found in these Milwaukee tests. Almost all of the larger material was removed with the first vacuum pass, but smaller fractions of the finer material were removed. This difference in sample recovery by particle size was much more pronounced for damp streets than for dry streets. It typically required two dry and one wet vacuumings to remove more than 90 percent of the different pollutants from the street surface in Bellevue. Pitt concluded that the loadings remaining on the street after a single dry vacuuming corresponded to the particulate material that was trapped within the texture of the street surface. The sampling equipment was more effective than the rains and the street cleaning equipment in removing street surface particulates; at no time were the street surface loadings undetectable during the study. Observed loadings represent the particulate loadings above the nonrecoverable loadings. The unrecovered base particulate loading values can be considered as a measuring datum that changes for different conditions.

Pitt felt that these datum levels slowly fluctuate when averaged through whole study basins. The expected fluctuation of the datum was estimated to be about 10 or 15 percent in each sampling period, well within the 25 percent sampling error. Most of the analyses considered relative changes in street

TABLE VI.8
EFFICIENCY TEST OF STREET SURFACE SAMPLING METHOD

Particle Size (Microns)	Loads Removed (g)			First Vac Efficiency (%)	Particle Size Distribution, %	
	First Vac	Second Vac & Wet Vac	Total		First Vac	Total
				New Concrete Streets		
#1 > 63	725.4	102.0	827.4	87	81	76
< 63	170.1	91.3	261.4	65	19	24
Total	895.5	193.3	1,088.8	82	100	100
#2 > 63	620.5	47.9	668.4	93	86	82
< 63	101.0	46.6	147.6	68	14	18
Total	221.5	94.5	816.0	88	100	100
				New Asphalt Streets		
#3 > 63	160.0	101.2	261.2	61	95	84
< 63	9.2	41.7	50.9	18	5	16
Total	169.2	142.9	312.1	54	100	100
#4 > 63	174.4	98.0	272.4	64	93	82
< 63	13.8	44.1	57.9	24	7	18
Total	188.2	142	330.3	57	100	100

surface loadings (comparing the initial to residual loads for street cleaning and rainfall events) and the change in street surface loading values with time.

These datum variations were less than the sampling errors associated with the number of subsamples obtained. Therefore, the sampling procedures were quite appropriate when the other errors in the sampling program are considered. The selected sampling procedures are sensitive to variations in loadings over large test areas which are much larger than the residual loading variations.

ATMOSPHERIC DEPOSITION QUALITY ASSURANCE

Laboratory quality assurance was an integral part of the atmospheric deposition monitoring program. Several of the constituents which were selected (i.e., pH and acidity) required immediate analyses and could not be sent to a distant laboratory without some change. Special tests were therefore made to determine the accuracy of the analyses. This program included acidity titrant standardization, measurement precision tests, distilled water tests, and a pH holding-time test.

Field versus Laboratory pH Measurements

Acidity and pH were analyzed immediately upon return from the field to prevent incorporation of atmospheric carbon dioxide into the sample (with subsequent lowering of the pH) by excessive splashing and prolonged exposure to air.

A test was conducted to determine whether there was a significant pH change when samples were transferred from field sites to the laboratory. Field pH readings were taken at the sites very soon after sample collection. Laboratory pH readings were later made after transportation to all the sites and following the entire atmospheric sample processing procedure (approximately three hours after field pick-up). All pH readings were made with an Orion Model 407A specific ion meter and a Ross Model 81-02 combination pH electrode which was calibrated once in the field and again at the lab.

Results of the pH test are shown on Table VI.9 and indicate that the lab pH values were about 0.03 pH units lower than the field pH values. This difference is very small, but suggests that some carbon dioxide increase in the sample may have occurred during transportation and processing of the samples. This difference, however, is probably within the analytical error range of the analysis. Based on these tests, it was concluded that laboratory pH measurements were acceptable (and more convenient).

Acidity Titrations and Titrant Standardization

Acidity titrations were more involved than pH measurements and required more extensive QA procedures. To ensure accuracy, the NaOH titrant was standardized periodically. Also, to determine the precision of the analyses (and analysts), replicate samples were analyzed on a routine basis.

The titrant and the titrant standardization solutions were prepared according to Standard Methods (APHA, et. al., 15th Edition, 1976). Dilute solutions

TABLE VI.9
TEST OF FIELD VS. LAB PH - 8/28/81

Station	Field pH	Lab pH	Difference
St. Bernadette's	3.60	3.59	-0.01
D.P.W.	3.80	3.72	-0.08
Appleton Avenue	3.60	3.69	+0.09
Telephone Company	3.70	3.70	0.00
Oil Gear	3.95	3.85	-0.10
West Allis	3.73	3.61	-0.12
SED Hq.	3.79	3.76	-0.03
Median	3.73	3.70	0.03

were prepared to accommodate the low range of un-buffered rainwater samples. The standardization solution was prepared using 0.5 g, $KHC_8H_4O_4$ rather than 10g $KHC_8H_4O_4$ per liter of CO_2-free distilled water, as is called for in Standard Methods. The NaOH titrant solution was used at 0.0013N.

Exactly 40 ml of the $KHC_8H_4O_4$ standard solution was measured in a pipet and transferred to a 150 ml beaker, while carefully avoiding splashing.

The NaOH (0.0013N) titrant was mixed thoroughly and a clean buret was filled and drained four times prior to titration. The titrant was added in 1 ml increments (while mixing slowly with a magnetic stirring bar) and the pH was recorded after each addition until a clear inflection point was reached at approximately pH 7.8 to 8.5. The resulting readings were plotted (ms NaOH added vs. pH) and the exact inflection point was determined from the graph. The actual normality of the NaOH titrant was then calculated (see Standard Methods, 15th Edition, p. 251). Three standardizations were conducted during the project period. Each standardization was very near to the expected NaOH normality of 0.0013N. The three standardized normalities were 0.00127, 0.00126 and 0.00125N.

Replicate Analyses

Sample precision replicates were analyzed for pH and acidity to determine variability within samples due to analyst and equipment error. On six separate occasions, acidity and pH samples were split into four aliquots and analyzed using methods described previously.

Results of the acidity precision test are reported in Table VI.10. Standard deviation values at the high and low ranges were calculated. The standard deviation of the acidity test at the 1.92 mg/l range was 0.156 mg/l (8.1% relative standard deviation), and the 7.72 mg/l range had a standard deviation of 0.290 mg/l (3.7% relative standard deviation). The mean of the acidity samples from the actual wet deposition data was 7.7 mg/l with a 4.7 mg/l standard deviation (108 samples) indicating a fairly high variability between samples. In accordance with the results of the precision test, the standard deviation of 0.29 mg/l at the 7.7 mg/l range is very small and should be well within the variability between samples and should not affect data interpretation.

The pH precision test data is shown on Table VI.11 and had a low range mean pH of 4.09 and a standard deviation of 0.009 pH units (0.22% relative standard deviation). The high range mean pH was 5.10 with a standard deviation of 0.036 (0.71% relative standard deviation). Standard Methods states that under carefully controlled laboratory conditions, a precision of 0.02 pH units can be obtained. The results of this pH precision test indicate similar findings. A pH precision test in the EPA Manual of Methods for Chemical Analysis of Water and Wastes (1974) indicates standard deviations in the pH 3.5 range of 0.10 and 0.11 pH units; much higher than the findings of this test.

Blank Analyses of Distilled and Deionized Water

Two distilled and six distilled-deionized water samples were analyzed for impurities to ensure the quality of the Q.A. blank samples. The distilled

TABLE VI.10

RESULTS OF ACIDITY PRECISION TEST (MG/L)

Sample #	Trial #1	Trial #2	Trial #3	Trial #4	Avg.	Standard Deviation	Relative Standard Deviation
1	5.17	4.74	4.71	4.55	4.79	0.265	5.5%
2	1.98	2.11	1.79	1.79	1.92	0.156	8.1%
3	7.47	7.47	8.04	7.88	7.72	0.290	3.7%
4	7.47	7.31	7.83	7.96	7.64	0.303	4.0%
5	4.31	4.31	4.48	4.58	4.42	0.133	3.0%
6	4.30	4.55	4.55	4.52	4.45	0.121	2.7%

Table VI.11
RESULTS OF PH PRECISION TEST

Sample #	Trial #1	Trial #2	Trial #3	Trial #4	Avg.	Standard Deviation	Relative Standard Deviation
1	4.50	4.55	4.52	4.55	4.53	0.024	0.53%
2	5.07	5.10	5.15	5.08	5.10	0.036	0.71%
3	4.10	4.10	4.10	4.10	4.10	0.000	0.00%
4	4.08	4.09	4.10	4.10	4.09	0.009	0.22%
5	4.55	4.60	4.54	4.56	4.56	0.026	0.57%
6	4.15	4.15	4.15	4.16	4.15	0.005	0.12%

water used in the DNR Southeast District laboratory for equipment cleaning, sample processing, and blank analysis was distilled in a Corning AG-II water still. Deionized water was obtained after distillation by passing the water through an ion-exchange column (manufactured by Horizon Ecology Co., Chicago, IL) which is capable of producing water with < 4 ug/l carbon dioxide and a resistivity of > 15 mohms/cm.

In 81 samples, the distilled water produced at the DNR Southeast District laboratory averaged 0.516 mohms/cm resistivity (1.94 umho/cm conductivity) with a standard deviation of 0.198 mohms/cm. According to the EPA Handbook for Analytical Quality Control in Water and Wastewater Laboratories, (USEPA, 1972), glass stills are capable of producing a distillate with a specific conductance of < 2 umho/cm, which agreed with the results from these tests.

The distilled-deionized water was also analyzed six times for total solids, soluble and total phosphorus, sulfate, total and soluble lead, nitrite plus nitrate-N, ammonia, chemical oxygen demand, and chloride. Total solids was the only constituent which had values higher than expected. In three of the six samples, total solids were > 15 mg/l. The remaining three total solids values and all values from the other constituents examined were at or below detection limits. The reason for the high total solids values in uncertain but, given that the other concentrations were low, it is possible that analytical error or sample container contamination may have been the problem.

Contamination of Wet Samples Due to Lid Seal Leakage

Due to an ineffective seal between the lid and buckets of the N-CON atmospheric deposition samplers, the lid gaskets were changed several times. Tests were conducted to determine the quantity of leakage contamination due to the poor seals. The "stock" seals on the transfer lids began to disintegrate early in the project. This material (a porous foam strip) visibly contaminated the wet/dry collection buckets and proved unacceptable. A second type of seal made of hard rubber replaced the original, but was also found to be unacceptable because it was unable to provide a tight seal. A third type of seal, made of a rubber-coated foam weather-stripping material, performed better than the previous two gaskets and was used at all sites until the conclusion of monitoring.

Special tests were conducted to determine the amount of sample contamination due to lid seal leakage. The test procedure consisted of placing a clean bucket into the atmospheric deposition sampler, with the lid cover, for several days. The bucket was then retrieved, processed, and analyzed according to the routine "dry" sample procedures described previously.

The "lid leakage" data was normalized for application to the wet atmospheric deposition sample data. The lid leakage data was reported by the laboratory in mg/l, and was converted to mg/hr, by calculating the number of hours the atmospheric sample bucket was exposed.

$$\frac{\text{L.L.} \times \text{Time}}{\text{Vol.} \times \text{Conc.}} \times 100 = \%\ \text{sample contamination}$$

where,
L.L. = median* lid leakage rate (mg/hr),
Time = median time (hours) between wet samples,
Vol. = median sample volume (liters), and
Conc. = median sampler concentration (mg/l).

*(Medians are used because the data is not normally distributed)

This data application reduces each contaminating constituent to a loading rate (mg/hr) and directly compares them through percent sample contamination (lid leakage vs. wet deposition sample concentration) for each constituent at each station. The results of the contamination rate calculations appear in Table VI.12. In some cases, the contamination percentages are high. The majority of the higher contamination percentages are probably due to: 1) the lid leakage rates were complied using "less than" detection limit concentrations at the detection limit (some "lid leakage" constituent concentrations were never above laboratory detection limits); 2) the wet deposition samples themselves had very small amounts of most measured constituents, and were at times very close to the detection limits.

The largest percent contamination was found for chloride, ranging from 46 to 90%. In most wet deposition samples, there were no chlorides detectable (< 2 mg/l). Lid leakage samples were also all below detection limits. When calculated at the detection limits, the blanks appear very near to the actual sample values, resulting in a high contamination rate. Therefore, the table values are all shown as ND (not detected).

The next highest contamination rates were found for soluble and total phosphorus, ranging from 9 to 19% and 4 to 15%, respectively. All the soluble phosphorus concentrations from the lid leakage samples were below laboratory detection (0.004 mg/l) values. Half of the total phosphorus (10 of 20) and total lead (10 of 20) contamination samples were also below detection levels (0.004 mg/l and 3 ug/l, respectively), as were 18 of 20 sulfate (4 mg/l) and 11 of 12 soluble lead (3 ug/l) samples.

Lid leakage contamination of "wet" samples represents a small portion of the total wet deposition values. The most representative constituents, due to the presence of few, if any, "less than" detection samples are total solids, nitrite plus nitrate-N, and ammonia. The contamination rates among these constituents were, in order, 4.8, 1.5, and 5.0%. These rates are higher than, for instance, the stormwater blanks, but this should be expected given the generally lower concentrations found in the wet deposition samples.

Collection Bucket Cleaning

Atmospheric deposition collection buckets and lids were hand-washed between samples using a plastic brush and a QED-II nonphosphorus soap solution. The soap solution was followed by three rinses with tap water and three rinses with distilled water. A sponge was later substituted for the brush to speed the washing process. Lint-free laboratory tissue was used to dry the buckets, while making an effort to avoiding fingerprinting any inner surface of the buckets.

TABLE VI.12
PERCENT LID LEAKAGE CONTAMINATION PER WET ATMOSPHERIC DEPOSITION SAMPLE

Station	Total Solids	Sol. P*	Total P	Total Pb	SO_4*	Sol. Pb*	NO_2NO_3-N	NH_3	CL*
P. Bernadette	4.5	ND	7.2	8.5	8.8	8.2	1.5	4.8	ND
D.P.W.	4.5	ND	11.2	7.6	6.6	9.0	1.5	5.2	ND
Appleton Ave.	4.4	ND	14.7	5.6	6.6	6.5	1.1	4.1	ND
Phone Co.	7.9	ND	11.3	8.2	10.3	12.2	1.6	6.0	ND
ED HQ	5.0	ND	8.1	12.3	13.4	14.5	2.1	6.5	ND
W. Allis	5.1	ND	7.9	6.0	8.6	7.5	1.3	3.7	ND
Wood	6.5	ND	4.0	3.0	6.4	7.5	0.8	2.6	ND
Oil Gear	3.6	ND	9.0	7.5	7.8	7.8	1.6	5.8	ND
Median	4.8	ND	8.6	7.6	8.2	8.0	1.5	5.0	ND
Mean	5.2	ND	9.2	7.3	8.6	9.2	1.4	4.8	ND

* These constituents (especially Cl, and Sol. P) are not representative due to all or a large majority of sample concentrations less than the laboratory detection limits (ND = not detected)

Bucket-washing blank samples were obtained to evaluate the quality of the washing program. Exactly 500 mls of distilled-deionized water was measured in a volumetric flask and poured into the bucket, where it remained for a sampling period. The bucket was then processed as a "dry precipitation" sample using previously described methods. The resulting blank sample was then analyzed for total solids, chemical oxygen demand, total lead, total phosphorus, sulfate, ammonia, and nitrite plus nitrate-N.

Results of the bucket-washing blanks were generally very good. All constituents, except total solids and COD, had very low concentrations relative to the atmospheric deposition samples. The highest total solids concentration detected was 18 mg/l and the highest COD concentration detected was 22 mg/l. Many of the samples were below laboratory detection limits for all chemical constituents.

Table VI.13 compares the median blank values with the sample values. The median of the total solids blanks, however, was 3.7 mg/l which was very low, even for blanks. The probability of exceeding the event mean concentration (EMC) was 0.2643, however. Two of the blank samples, both taken on 6/9/82 were high in total solids (17.5, 7.5 mg/l) and COD (both 22 mg/l) and corresponded to high rooftop runoff blanks and other blanks run of this same day. The cause was probably a problem with the distilled-deionized water used as a medium for these blank samples. If these two blanks are left out of the calculations, the median then becomes 2.5 mg/l with a 0.1841 probability of exceeding the EMC. This is a lower median value, but it still has a relatively high probability of exceeding the EMC. The only explanation possible is that total solids are very low in the wet deposition samples.

The COD blank median (5 mg/l) also had a high probability of exceeding the EMC. Even if the two high values (22 mg/l) are removed, the median remains the same. Seven of the ten samples had less than the detection limit of 5 mg/l. Thus, because these values are calculated as 5 mg/l and not less than 5 mg/l, the probability of exceeding the EMC (which is very low) is still 0.2981. All other constituent probabilities were very low.

Replication of Atmospheric Samples at One Site

A replicate sampling program was initiated at the West Allis City Hall site to describe the variability of samples obtained from adjacent atmospheric deposition samplers. Two identical N-CON atmospheric samplers were placed next to each other on the roof of the City of West Allis municipal building (Storet #413708) and duplicate wet and dry atmospheric samples were obtained for the months of May and June, 1982. The samples were collected simultaneously from both samplers, following the routine sampling procedures. Sample processing and analyses were also completed following the previously described procedures. Table VI.14 summarizes these results.

The chemical concentrations resulting from this test indicate that the samplers were very similar for all constituents in both wet and dry deposition samples. Four dry, and eight wet deposition sample sets were collected simultaneously by the duplicate samplers at the established West Allis sampler location.

TABLE VI.13
PROBABILITY OF A WET DEPOSITION EVENT SAMPLE BEING LESS THAN THE BUCKET BLANK MEDIAN

Parameter	Blank Median (mg/l)	Prob. of Exceeding EMC*
Total Lead	0.003	0.026
COD	5**	0.30
Sulfate	1	0.0055
Total Solids	3.7	0.26
Total Phosphorus	0.001	0.0001
Ammonia	0.01	0.0001
Nitrite plus Nitrate-N	0.005	0.031

*EMC : event mean concentration

**laboratory detection limit is 5 mg/l

TABLE VI.14
STATISTICAL SUMMARY OF ATMOSPHERIC DEPOSITION REPLICATE DATA USING THE MANN-WHITNEY TEST (H_0:SAMPLER 1 = SAMPLER 2)

Dry Deposition	Level of Significance (*)
Total Solids	0.67
C.O.D.	1.00
Total Lead	0.89
Total Phosphorus	0.89
Sulfate	0.19
Wet Deposition	
Total Phosphorus	0.87
Total Lead	0.95
Sulfate	0.66
Nitrite plus Nitrate-N	1.00
Ammonia	0.77
pH	0.51
Acidity	1.00

---

* = alpha, where the probability of a significant difference is equal to 1-. As an example, the probability of a significant difference for total solids = 1-0.665 = 0.335, or 34 percent. An alpha value of 0.05 (for a probability value of 0.95) is usually considered significant.

Mann-Whitney statistical tests were applied to each individual constituent, to combined dry constituents, and to combined wet constituents. The Mann-Whitney test is a non-parametric test and relies on a rank sum, thus it can be applied to non-normal populations and is not adversely affected by outliers. All tests indicated that the null hypothesis (no differences between samplers) could not be rejected at the 95% (alpha = 0.05) confidence level. Sulfate and pH were the only two constituents which had fairly high rejection confidence levels (81% and 49%, respectively); all others ranged from 33% to 0%. The combined data from all samples (both wet and dry) from the duplicate samplers were subtracted from the corresponding combined West Allis data and a Student's "T"-Test was performed on the differences. The T-Test was used because the combined samples resulted in a normal distribution. This test also indicated a very strong similarity between the data sets collected by the two samplers.

Atmospheric Deposition Sampling Problems

Several wet/dry deposition samples were not analyzed or collected due to obvious contamination and collector malfunctions such as:

- Improper lid alignment.
- Auto sension grid malfunction caused by mineralization (fouling) on the grid and resulting in lid return failure (rain bucket left exposed).
- Electronics (control box) malfunction.
- Material breakdown of lid gaskets and glue.

Natural and other circumstances:

- Contamination from bird droppings (samples were always discarded).
- Bucket loss due to high winds.
- Delayed sample pick-up resulting in questionable sample integrity due to possible chemical changes (samples discarded).

Procedure for Handling "Not-Detectable" Reported Concentrations

There were problems with detection limits for total solids and total phosphorus for wet deposition samples. For total phosphorus, detection limits of 0.020 and 0.004 mg/l were used. Many sample concentrations fell between 0.010 and 0.004 mg/l. Using one-half of the "less than" values for calculations was unrealistic, given the low concentration values. For total phosphorus, all values of < 0.020 mg/l were discarded and values of <0.004 mg/l were assumed to be 0.002 mg/l (using one-half of the detection limits, as for the other samples and constituents).

For total and suspended solids, a detection limit of 2 mg/l was generally used, and is reasonable. A detection limit of 5 mg/l was used for four measurements, which were discarded. A number of values of '0' (zero) were also reported. This implies "not detected". A value of < 2 mg/l was assumed. Values of < 4 mg/l SO_4 were eliminated for calculating distributions.

As noted above, one-half of the detection limit was used for the "ND" sample concentration, unless the number of values at the detection limit were numerous.

ROOFTOP SAMPLING QUALITY ASSURANCE

The QA aspects of the rooftop sampling program element involved checking the adaquacy of sample collection container washing and investigating potential sample contamination by the sample. The rest of this subsection discusses special tests which were conducted to investigate these issues.

Washing of Rooftop Sample Collection Containers

The 5-gallon, wide-mouth rooftop runoff collection buckets were hand-washed after each use. The buckets were scrubbed, first with a plastic brush on an extension handle, and later with an synthetic sponge to speed-up the process. The first washings were with a QED-II non-phosphorus soap solution. This was followed by three tap-water rinses and three distilled water rinses. The last several washes were with an Alconox soap solution used after the QED-II supply was depleted. Alconox contains approximately 45% phosphorus.

Blank samples were taken to monitor the effectiveness of the cleaning procedure. Exactly 1000 ml of distilled-deionized water was measured in a volumetric flask and poured into a clean bucket. The bucket was then scrubbed with a clean brush as with an event sample. The resulting sample was then poured through a cleaned USGS DECA cone-splitter into appropriate sample bottles. The samples were preserved and immediately sent to the Wis. State Lab of Hygiene for analysis of total solids, total phosphorus, ammonia, nitrite plus nitrate-N, total lead, total zinc, COD, total cadmium, and sulfate. A total of eight bucket-washing blanks were analyzed. Table VI.15 shows the results of these blank analyses.

The results of the rooftop runoff bucket washing blanks generally indicated a low rate of bucket contamination. There were some samples which showed possible contamination however. The percentage of the blank concentrations compared to the sample concentrations is also presented on Table VI.15.

Two blank samples, both taken on 6/9/82 had high concentrations of COD (46 and 50 mg/l) and total solids (10 and 20 mg/l). Atmospheric bucket-washing blanks were also taken on this day and both of these also had high COD and total solids concentrations. It is suspected that the source of this contamination was the deionization column used to deionize the water which was used as a medium for both sets of blanks.

Based on a comparison of the means, the overall percentage of COD and total solids contamination was 38.0% and 9.7%, respectively. If the two suspect samples are eliminated, all of the COD blanks are less than or equal to the 5 mg/l laboratory detection limit, and the total solids contamination percentage drops to 7.6%.

The remaining high contamination percentages are associated with total cadmium, sulfate, and total lead. All of the sulfate blank concentrations were below laboratory detection limits and all but one each of the total cadmium and total lead blank concentrations were below detection limits (0.2 mg/l and 3 mg/l, respectively). All of the remaining construents were below a 3% maximum contamination value.

TABLE VI.15
ROOFTOP RUNOFF BUCKET-WASHING BLANK CONCENTRATIONS (mg/l)

Date	Tot.Sol.	Tot.P	NH4	NO_2+NO_3-N	Total Lead	Total Zinc	C.O.D.	Total Cadium	SO_4
2/1/82	20	0.004	0.18	0.02	0.003	0.020	5	0.0002	4
2/1/82	15	0.004	0.02	0.02	0.003	0.020	5	0.0002	4
4/12/82	2	0.000	0.01	0.00	0.003	0.020	5	0.0002	1
4/12/82	5	0.005	0.02	0.01	0.003	0.020	5	0.0002	1
4/29/82	0	0.001	0.00	0.01	0.003	0.020	5	0.00003	1
4/29/82	0	0.001	0.01	0.00	0.003	0.020	5	0.00002	1
6/9/82	20	0.003	0.02	0.01	0.003	0.020	50	0.00002	1
6/9/82	10	0.001	0.03	0.00	0.003	0.020	46	0.00002	1
Blank Mean	9	0.002	0.03	0.01	0.003	0.020	16	0.0001	2
Runoff Sample Mean	93	0.079	1.03	1.21	0.075	0.826	42	0.0010	13.7
Percent Contamination	9.7	2.5	2.9	0.8	4.0	2.4	38.0	10.0	13.1

Possible Zinc Contamination Of Rooftop Runoff Samples

The goal of this test was to determine if the residential rooftop runoff samples were accurately representing the rooftop runoff quality. High total zinc (Zn) concentrations (up to 6500 mg/l) were found in the residential and Wood Center commercial rooftop runoff samples. As described previously, the residential rooftop runoff samplers were constructed of galvanized steel gutter material to simulate the runoff as it leaves the roof via the gutters and downspout. The galvanizing process deposits a protective coating of zinc to steel or iron to prevent rust. There was concern that the samplers, constructed of recently galvanized steel, would leach more zinc into the samples than is normally leached from older, more weathered gutters and downspouts.

In an effort to determine if there was zinc contamination, sample sets were taken from three events (5/21, 5/26, and 9/23/82). Each sample set included a sample from the downspout, the sampler, and the roof itself (before contact with the sampler or downspout). The samples were taken by hand with clean, polyethylene bottles and sent, (following preservation with nitric acid to a pH 2) to the Wis. State Lab of Hygiene for analysis of total zinc, total lead (5/21 and 5/26 only) and total cadmium (5/21 and 5/26 only). In addition, pH values were also obtained for the 5/21 and 9/23/82 samples.

All three samples were from the Sylvester residential site. The roof at the Sylvester site was in good repair, although the gutter was slightly rusted. The exterior of the gutter and downspout was painted. There was no obvious material in the gutter which might have altered the chemical concentrations.

The zinc analyses (Table VI.16) indicate that the vast majority of total zinc in the rooftop runoff samples originates from contact with the sampler or the gutter. The zinc concentrations from the roof itself (bypassing the gutter and sampler) are an average of 12 times lower than from the gutter or downspout. The samplers have an average zinc concentration 18% higher than the samples taken directly from the downspout. The largest difference occurred on 9/23/82, in which the total zinc concentration from the sampler (1100 mg/l) was 47% higher than that of the downspout sample (750 mg/l). The zinc concentrations from the other two sample sets show that the samplers had an average zinc concentration only 1% higher than the direct downspout samples. The reason for the high zinc sampler concentration on 9/23/82 is unclear. The pH of the samples were measured at 6.15 for the roof, 6.25 for the sampler and 6.60 for the downspout. The solubility of zinc does increase when the pH decreases from 6.6 to 6.3, but detention time (for equilibration) and other factors are also important. The pH values taken on 5/21 were higher (less acid) and the corresponding zinc levels were lower than those of 9/32.

Total lead and total cadmium were also analyzed for the 5/21 and 5/26 sample sets. The total lead values did not vary significantly between the different samples, as did the zinc concentrations. Total cadmium concentrations were relatively low (0.2-2.6 mg/l), and showed a possible, but weak trend toward higher concentrations from the downspout samples (possibly from paint).

The flat commercial rooftop runoff samples from Wood Center on 6/15 and 6/29/82 have zinc concentrations of 250 and 740 mg/l. Corresponding samples

TABLE V.16
SOURCE OF POSSIBLE METAL CONTAMINATION IN ROOFTOP RUNOFF SAMPLES (MG/L)

Sampling Date	Roof	Downspout	Sampler
		Total Zinc	
5/21/82	70	520	460
5/26/82	30	640	690
9/23/82	60	750	1100
Mean	53	637	750
		Total Lead	
5/21/82	50	33	41
5/26/82	68	56	42
Mean	59	45	42
		Total Cadmium	
5/21/82	0.4	2.6	0.2
5/26/82	0.2	1.4	1.3
Mean	0.3	2.0	0.8

from the West Allis flat rooftop had zinc concentrations of 120 and 140 mg/l. The Wood Center samples were taken from a galvanized steel downspout, whereas the West Allis samples were taken from a cast-iron pipe (possibly containing other metals). Again, it is suspected that the majority of zinc in the rooftop runoff at Wood Center originated from contact with the galvanized steel downspout, although a "control" sample, taken before contact with the downspout, was not available for verification.

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Appendix A

NATIONWIDE URBAN RUNOFF PROGRAM
1980
Milwaukee County, Wisconsin
Study Site Urban Lot Inventory
Southeastern Wisconsin Regional Planning Commission

No. ____________

Study Area ☐ ______________________________

Block and Lot Number ☐☐☐☐ Address ____________________ Map # ☐

Township Range Section 1/4 section ☐☐ ☐☐ ☐☐ ☐ Civil Division ☐☐

Date of Inventory 19☐☐ ☐☐ ☐☐ Prepared by ______
Year Month Day

							Comments	For D.P. U
1 LAWN								
a percent slope	☐ low	☐ med	☐ high					☐
b sod condition	☐ exc.	☐ good	☐ fair	☐ poor				☐
c stock piled material-type	☐ soil	☐ gravel	☐ rubbish	☐ other—describe				☐☐☐
-location in yard	☐ front	☐ back	☐ side	☐ street r o w	☐ adjacent to bldg.	☐ other—describe		☐☐☐
d ungrassed eroded areas	☐ front	☐ back	☐ side	☐ street r o w	☐ adjacent to bldg.	☐ other—describe		☐☐☐
-approximate size (ft²)	☐☐☐							☐☐☐
e garbage storage site	☐ back yard	☐ side yard	☐ by garage	☐ unknown	☐ other—describe			☐☐☐
-condition	☐ exc.	☐ good	☐ fair	☐ poor				☐
-container used	☐ bag	☐ can	☐ unknown	☐ other				☐☐☐
f area adjacent to building	☐ grass	☐ garden	☐ bushes	☐ gravel	☐ exposed soil	☐ other—describe		☐☐☐
-condition	☐ exc.	☐ good	☐ fair	☐ poor				☐
2 LITTER								
a amount	☐ none	☐ light	☐ moderate	☐ high				☐
b location	☐ front	☐ back	☐ side	☐ street r o w	☐ street	☐ other—describe		☐☐☐
c material	☐ plastic	☐ paper	☐ bottles	☐ cans	☐ organic	☐ other—describe		☐☐☐
3 DOGS								
a present	☐ yes	☐ unknown						☐
b outside pen or chain	☐ pen	☐ chain	☐ other	☐ unknown				☐☐☐
-location	☐ front	☐ back	☐ adjacent to bldg	☐ other—describe				☐☐☐
c waste on lot	☐ yes	☐ no						☐
-location	☐ front	☐ back	☐ street r o w	☐ other—describe				☐☐☐
4 GARAGE								
a present	☐ yes, attached	☐ yes, detached	☐ no					☐
b material building	☐ wood	☐ stone/brick	☐ siding	☐ other—describe				☐☐☐
-roof	☐ shingle	☐ roll	☐ other—describe					☐☐☐
c condition	☐ exc.	☐ good	☐ fair	☐ poor				☐
d #spaces for cars	☐ one	☐ two	☐ three	☐ four	☐ other—describe			☐

MISC COMMENTS

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NURP URBAN LOT INVENTORY

P 2/2

5 GUTTERS AND DOWNSPOUTS

Comments — For D.P. Use

a. on house-condition ☐ exc. ☐ good ☐ fair ☐ poor ☐ none ____ ☐

-drains to: ☐ lawn ☐ adjacent to bldg ☐ driveway ☐ storm sewer ☐ unknown other-describe ____ ☐☐☐

b. on garage-condition ☐ exc. ☐ good ☐ fair ☐ poor ☐ none ____ ☐

-drains to ☐ lawn ☐ adjacent to bldg ☐ driveway ☐ storm sewer ☐ unknown ☐ other-describe ____ ☐☐☐

6 SIDEWALK

a. to building-material ☐ concrete ☐ asphalt ☐ gravel ☐ dirt ☐ none ☐ other-describe ____ ☐☐☐

-condition ☐ exc ☐ good ☐ fair ☐ poor ____ ☐

-width ☐☐ inches ____ ☐☐

b. in street r.o.w.-material ☐ concrete ☐ asphalt ☐ gravel ☐ dirt ☐ none ☐ other-describe ____ ☐☐☐

-condition ☐ exc. ☐ good ☐ fair ☐ poor ____ ☐

-width ☐☐ inches ____ ☐☐

7 DRIVEWAY

a. material ☐ concrete ☐ asphalt ☐ gravel ☐ dirt ☐ none ☐ other-describe ____ ☐☐☐

b. condition ☐ exc ☐ good ☐ fair ☐ poor ____ ☐

c. slope ☐ low ☐ med ☐ high ____ ☐

d. width ☐ one car ☐ two cars ☐ other—describe ____ ☐

8 OFF-STREET PARKING (other than driveway parking)

a. material ☐ concrete ☐ asphalt ☐ gravel ☐ dirt ☐ none ☐ other-describe ____ ☐☐☐

b. condition ☐ exc. ☐ good ☐ fair ☐ poor ____ ☐

c. # spaces for cars ☐☐ ____ ☐☐

d. # cars present ☐☐ ____ ☐☐

e. parking restrictions ☐ meter (___hrs. max.) ☐ sign (___hrs. max.) ☐ none ☐ other-describe ____ ☐

9 CONSTRUCTION

a. location ☐ front ☐ back ☐ side ☐ street r.o.w. ☐ adjacent to bldg ☐ other-describe ____ ☐☐☐

b. description type ____ size of area ____

e. erosion control measures ☐ no ☐ yes, describe ____ ☐

10 TREES AND HEDGES

a. trees

	No. of Deciduous			No. of Coniferous			
	sm	med.	lge.	sm	med.	lge.	
front	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	←
back	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	←
street r.o.w.	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	←

b. hedges-location ☐ front ☐ back ☐ side ☐ adjacent to bldg ☐ none ☐ other-describe ____ ☐☐☐

-length in feet (approx.) ☐☐☐ ____ ☐☐☐

c. debris on lawn ☐ leaves ☐ seed/fruit/flowers ☐ branches ☐ none ☐ other-describe ____ ☐☐☐

-location ☐ front ☐ back ☐ side ☐ adjacent to bldg ☐ street r.o.w. ☐ other-describe ____ ☐☐☐

No. __________

NATIONWIDE URBAN RUNOFF PROGRAM
1980
Milwaukee County, Wisconsin
Study Site Street/Alley Inventory
Southeastern Wisconsin Regional Planning Commission

Study Area ☐ ____________________

Map # ☐

Township Range Section 1/4 section ☐☐ ☐☐ ☐☐ ☐

Civil Division ☐☐

Date of Inventory 19☐☐ ☐☐ ☐☐ Time ☐☐:☐☐
Year Month Day

Prepared by ____

Street name: ____________________

between ____________________ and ____________________

Alley parallel to ____________________ and ____________________

between ____________________ and ____________________

(alley inventory: complete numbers 1, 5, and 6 only)

1. ROAD | Comments | For D.P.

a. general ☐☐ width (ft.) ☐☐ pavement surface condition rating ____________ ☐☐☐
☐ # driving lanes ☐ # parking lanes ____________ ☐☐
☐ one-way ☐ two-way ____________ ☐

b. longitudinal slope ☐ low ☐ med. ☐ high ____________ ☐

c. surface material ☐ concrete ☐ asphalt ☐ gravel ☐ dirt ☐ oil screen ☐ other—describe ____________ ☐☐☐

2. MEDIAN STRIP

a. width ☐☐ ft. (use 00 for none) ____________ ☐☐

b. material ☐ grass ☐ dirt ☐ gravel ☐ concrete ☐ asphalt ☐ other—describe ____________ ☐☐☐

c. condition ☐ exc. ☐ good ☐ fair ☐ poor ____________ ☐

3. CURB LAWN

a. even side-width ☐☐☐ inches ____________ ☐☐☐

-material ☐ grass ☐ dirt ☐ gravel ☐ concrete ☐ asphalt ☐ other—describe ____________ ☐☐☐

-condition ☐ exc. ☐ good ☐ fair ☐ poor ____________ ☐

b odd side-width ☐☐☐ inches ____________ ☐☐☐

-material ☐ grass ☐ dirt ☐ gravel ☐ concrete ☐ asphalt ☐ other—describe ____________ ☐☐☐

-condition ☐ exc. ☐ good ☐ fair ☐ poor ____________ ☐

4. CURB AND GUTTER

a. even side-dimensions ☐☐ curb height (inches) ☐☐ gutter width (inches) ____________ ☐☐☐

-material ☐ concrete ☐ asphalt ☐ none ☐ other—describe ____________ ☐☐☐

-condition ☐ exc. ☐ good ☐ fair ☐ poor ____________ ☐

b odd side-dimensions ☐☐ curb height (inches) ☐☐ gutter width (inches) ____________ ☐☐☐

-material ☐ concrete ☐ asphalt ☐ none ☐ other—describe ____________ ☐☐☐

-condition ☐ exc. ☐ good ☐ fair ☐ poor ____________ ☐

NURP STREET/ALLEY INVENTORY

P 2/2

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5. CATCH BASINS

Comments — For D P Use

a. even side–locations ☐ corner ☐ mid-block ☐ center of street/alley ☐ other—describe ________ ☐☐☐☐

–conditions ☐ # blocked w/debris ☐ # clear ☐ # partly clear ☐ # not determined ________ ☐☐☐☐

b. odd side-locations ☐ corner ☐ mid-block ☐ center of street/alley ☐ other—describe ________ ☐☐☐☐

–conditions ☐ # blocked w/debris ☐ # clear ☐ # partly clear ☐ # not determined ________ ☐☐☐☐

---

6. INLETS

a. even side–location ☐ corner ☐ mid-block ☐ center of street alley ☐ other—describe ________ ☐☐☐☐

–condition ☐ # blocked w/debris ☐ # clear ☐ # partly clear ☐ # not determined ________ ☐☐☐☐

b. odd side–locations ☐ corner ☐ mid-block ☐ center of street/alley ☐ other—describe ________ ☐☐☐☐

–conditions ☐ w/debris ☐ clear ☐ clear ☐ # not determined ________ ☐☐☐☐

---

7. STREET PARKING

a. even side–type ☐ off-street ☐ on-street ☐ both ☐ none ☐ other—describe ________ ☐☐☐

–restrictions ☐ meter ______ hours max ________ ☐

☐ posted ______ hours max ________ ☐

☐ restricted hours from _____ to _____ describe ________ ☐

☐ no restrictions ________ ☐

☐ other–describe ________ ☐

–car-occupied curb ☐☐ percent ________ ☐☐

b. odd side–type ☐ off-street ☐ on-street ☐ both ☐ none ☐ other—describe ________ ☐☐☐

–restrictions ☐ meter ______ hours max ________ ☐

☐ posted ______ hours max ________ ☐

☐ restricted hours from _____ to _____ describe ________ ☐

☐ no restrictions ________ ☐

☐ other–describe ________ ☐

–car-occupied curb ☐☐ percent ________ ☐☐

---

8. TRAFFIC

a. posted speed limit ☐☐ mph (use 00 if not posted) ________ ☐☐

b. volume ☐ light ☐ moderate ☐ heavy ________ ☐

c. traffic control ☐ stop sign ☐ stop lights ☐ flow-through ☐ yield ☐ dead end ☐ other—describe ________ ☐☐☐

MISC COMMENTS

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Exterior Housing Condition Rating Form

No. ____________

Date of Rating mo. ☐☐ day ☐☐   Tn. ☐☐ Rn. ☐☐ Sec. ☐☐ ¼ ☐

Rated by ____________

Civil Division ☐☐☐

Units Occupied ☐☐   Units Vacant ☐☐   Seasonal ☐   Under Construction ☐

STRUCTURE CLASSIFICATION				TYPE OF CONSTRUCTION	
1. SINGLE FAMILY 2. TWO FAMILY 3. MULTI-FAMILY	4. MOBILE HOME 5. MIXED USE ☐	NO. OF UNITS IN STRUCTURE ☐☐	NO. OF STORIES ☐☐	1. WOOD FRAME 2. METAL 3. CONCRETE	4. STRUCTURAL MASONRY 5. OTHER 6. UNKNOWN ☐

MAJOR COMPONENTS				
EXTERIOR ITEMS[a]	MATERIAL	CONDITION	VALUE 4 8 12 16	REMARKS
FOUNDATION 1. OK 2. NOT OK ☐	1. STONE 2. WOOD 3. BLOCK 4. CONCRETE 5. POST OR PIER 6. BRICK 7. SLAB 8. OTHER 9. NONOBSERVABLE ☐☐☐ 1st2nd3rd	LEANING	☐☐☐☐	
		BOWED	☐☐☐☐	
		CRACKED	☐☐☐▨	
		MISSING MATERIALS	☐☐☐▨	
EXTERIOR WALL 1. OK 2. NOT OK ☐	NOT APPLICABLE	LEANING	☐☐☐☐	
		BOWED	☐☐☐☐	
		CRACKED (MASONRY)	☐☐☐▨	
		MISSING MATERIALS (MASONRY)	☐☐☐▨	
ROOFING 1. OK 2. NOT OK ☐	1. SHINGLE 2. ROLL 3. OTHER 4. NONOBSERVABLE ☐☐☐ 1st2nd3rd	SAGGING	☐☐☐☐	
		BOWED	☐☐☐☐	
		HOLE OR WORN	☐☐☐☐	
		MISSING MATERIALS	☐☐☐☐	
	MINOR COMPONENTS		1 2 3 4	
CHIMNEY 1. OK 2. NOT OK ☐	1. BRICK 2. BLOCK 3. METAL 4. OTHER 5. NONOBSERVABLE ☐☐☐ 1st2nd3rd	MAKESHIFT	☐☐☐☐	
		LEANING	☐☐☐☐	
		MISSING MATERIALS	☐☐☐☐	
GUTTERS & DOWNSPOUTS 1. OK 2. NOT OK ☐	1. WOOD 2. METAL 3. PLASTIC 4. OTHER 5. NONOBSERVABLE ☐☐☐ 1st2nd3rd	ROTTED	☐☐☐☐	
		HOLE	☐☐☐☐	
		LOOSE	☐☐☐☐	
		MISSING MATERIALS	☐☐☐☐	

MINOR COMPONENTS							
EXTERIOR ITEMS*	MATERIAL	CONDITION	VALUE				REMARKS
			1	2	3	4	
EAVES & FACIA 1. OK 2. NOT OK ☐	1. WOOD 2. METAL 3. PLASTIC 4. MASONRY 5. COMPOSITION BOARD 6. OTHER 7. NONOBSERVABLE ☐☐☐ 1st 2nd 3rd	CRACKED	☐	☐	☐	☐	
		ROTTED	☐	☐	☐	☐	
		HOLE	☐	☐	☐	☐	
		MISSING MATERIALS	☐	☐	☐	☐	
SIDING 1. OK 2. NOT OK ☐	1. WOOD 2. ALUMINUM 3. BRICK, BLOCK, OR STONE 4. ASPHALT 5. ASBESTOS 6. OTHER 7. NONOBSERVABLE ☐☐☐ 1st 2nd 3rd	BROKEN	☐	☐	☐	☐	
		CRACKED	☐	☐	☐	☐	
		WEATHERED	☐	☐	☐	☐	
		MISSING MATERIALS	☐	☐	☐	☐	
WINDOWS & DOORS 1. OK 2. NOT OK ☐	1. METAL 2. WOOD 3. OTHER 4. NONOBSERVABLE ☐☐☐ 1st 2nd 3rd	BROKEN	☐	☐	☐	☐	
		LEANING	☐	☐	☐	☐	
		ROTTED	☐	☐	☐	☐	
		MISSING MATERIALS	☐	☐	☐	☐	
PORCH 1. OK 2. NOT OK ☐	1. WOOD 2. CONCRETE 3. BRICK 4. BLOCK 5. OTHER 6. NONOBSERVABLE ☐☐☐ 1st 2nd 3rd	ROTTED	☐	☐	☐	☐	
		BROKEN	☐	☐	☐	☐	
		MISSING MATERIALS	☐	☐	☐	☐	
		SAGGING	☐	☐	☐	☐	
PAINTING 1. OK 2. NOT OK ☐		EAVES & FACIA	☐	☐	☐	☐	
		WALLS	☐	☐	☐	☐	
		WINDOWS & DOORS	☐	☐	☐	☐	
		GUTTERS & DOWNSPOUTS	☐	☐	☐	☐	
		PORCH	☐	☐	☐	☐	

*If an exterior item cannot be seen, such as the roof of a tall building, use code no. 9.

OUT-BUILDINGS		
	Good	Poor
Structure	☐	☐
Painting	☐	☐
Accessories	☐	☐

IMMEDIATE NEIGHBORHOOD				
		Good	Poor	None
PUBLIC	**Walks**	☐	☐	☐
	Streets & Roads	☐	☐	☐
	Lighting	☐	☐	☐
	Landscaping	☐	☐	☐
PRIVATE	Housing	☐	☐	☐
	Yards	☐	☐	☐

No ____

NATIONWIDE URBAN RUNOFF PROGRAM
1980
Milwaukee County, Wisconsin
Study Site Parking Lot Inventory
Southeastern Wisconsin Regional Planning Commission

Study Area ☐ ____

Block and Lot Number ☐☐☐☐ Address ____

Township ☐☐ Range ☐☐ Section ☐☐ 1/4 section ☐

Date of Inventory 19☐☐ (Year) ☐☐ (Month) ☐☐ (Day)

Map # ☐

Civil Division ☐

Prepared by ____

Comments — For D

1. LAWN

a. percent slope ☐ low ☐ med. ☐ high ____ ☐

b. sod condition ☐ exc. ☐ good ☐ fair ☐ poor ____ ☐

c. stock piled material-type ☐ soil ☐ gravel ☐ rubbish ☐ other—describe ____ ☐

-location in yard ☐ front ☐ back ☐ side ☐ street r.o.w. ☐ adjacent to bldg. ☐ other—describe ____ ☐

d. ungrassed/eroded areas ☐ front ☐ back ☐ side ☐ street r.o.w. ☐ adjacent to bldg. ☐ other—describe ____ ☐

-approximate size (ft²) ☐☐☐ ____ ☐

e. garbage storage site ☐ back yard ☐ side yard ☐ by garage ☐ unknown ☐ other—describe ____ ☐

-condition ☐ exc. ☐ good ☐ fair ☐ poor ____ ☐

-container used ☐ bag ☐ can ☐ unknown ☐ other ____ ☐

f. area adjacent to building ☐ grass ☐ garden ☐ bushes ☐ gravel ☐ exposed soil ☐ other—describe ____ ☐

-condition ☐ exc ☐ good ☐ fair ☐ poor ____ ☐

2. LITTER

a. amount ☐ none ☐ light ☐ moderate ☐ high ____ ☐

b. location ☐ front ☐ back ☐ side ☐ street r.o.w ☐ street ☐ other—describe ____ ☐

c. material ☐ plastic ☐ paper ☐ bottles ☐ cans ☐ organic ☐ other—describe ____ ☐

3. CONSTRUCTION

a. location ☐ front ☐ back ☐ side ☐ street r.o.w. ☐ adjacent to bldg ☐ other-describe ____ ☐

b. description type ____ size of area ____

e. erosion control measures ☐ no ☐ yes, describe ____ ☐

4. TREES AND HEDGES

a. trees

	No. of Deciduous			No. of Coniferous		
	sm.	med	lge.	sm.	med.	lge.
front	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐
back	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐
street r.o.w.	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐

b. hedges-location ☐ front ☐ back ☐ side ☐ adjacent to bldg ☐ none ☐ other-describe ____ ☐

-length in feet (approx.) ☐☐☐ ____ ☐

c. debris on lawn ☐ leaves ☐ seed/fruit/flowers ☐ branches ☐ none ☐ other-describe ____ ☐

-location ☐ front ☐ back ☐ side ☐ adjacent to bldg ☐ street r.o.w ☐ other-describe ____ ☐

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5. MEDIAN STRIP

a. width ☐☐ ft. (use 00 for none)

b. material ☐ grass ☐ dirt ☐ gravel ☐ concrete ☐ asphalt ☐ other—describe ______

c. condition ☐ exc. ☐ good ☐ fair ☐ poor ______

6. SIDEWALK

a. to building-material ☐ concrete ☐ asphalt ☐ gravel ☐ dirt ☐ none ☐ other-describe ______

-condition ☐ exc. ☐ good ☐ fair ☐ poor ______

-width ☐☐ inches ______

in street r.o.w.-material ☐ concrete ☐ asphalt ☐ gravel ☐ dirt ☐ none ☐ other-describe ______

-condition ☐ exc. ☐ good ☐ fair ☐ poor ______

-width ☐☐ inches ______

7 ENTRANCES

material ☐ concrete ☐ asphalt ☐ gravel ☐ dirt ☐ none ☐ other-describe ______

condition ☐ exc. ☐ good ☐ fair ☐ poor ______

slope ☐ low ☐ med. ☐ high ______

width ☐ one car ☐ two cars ☐ other—describe ______

number ☐☐

CATCH BASINS — Comments — For D P. Use

even side-locations ☐ corner ☐ mid-block ☐ center of street/alley ☐ other—describe ______

-conditions ☐ # blocked w/debris ☐ # clear ☐ # partly clear ☐ # not determined ______

odd side-locations ☐ corner ☐ mid-block ☐ center of street/alley ☐ other—describe ______

-conditions ☐ # blocked w/debris ☐ # clear ☐ # partly clear ☐ # not determined ______

9 INLETS

even side-location ☐ corner ☐ mid-block ☐ center of street/alley ☐ other—describe ______

-condition ☐ # blocked w/debris ☐ # clear ☐ # partly clear ☐ # not determined ______

odd side-locations ☐ corner ☐ mid-block ☐ center of street/alley ☐ other—describe ______

-conditions ☐ w/debris ☐ clear ☐ clear ☐ # not determined ______

0. PARKING LOT SURFACE

material ☐ concrete ☐ asphalt ☐ gravel ☐ dirt ☐ none ☐ other-describe ______

Pavement Surface ~~condition~~ Rating ☐☐

spaces for cars ☐☐☐☐ ______

cars present ☐☐☐☐ ______

parking restrictions ☐ meter (__ hrs max.) ☐ sign (__ hrs max.) ☐ none ☐ other-describe ______

area of lot (ft x 10³) ☐☐☐☐

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APPENDIX B
Quality Assurance Procedures to Obtain Blanks for Water Quality Analyses
(Updated 9/22/80)

I. Bottle Washing

Bottles used in the Manning samplers are all washed at the SED facility. Q.A. is maintained by following these procedures.

1. Set dirty Manning bottles into yellow Manning base. Place retaining ring into base. Put base on wash racks.
2. Start power washer. Set soap mix to indicated level and wash bottles with power spray insuring that corners of bottles are hit with force of spray. 10-15 seconds per bottle is sufficient.
3. Set soap mix to zero position and rinse bottles with normal tap water.
4. Turn base over to top rack so bottle openings are facing down. Take hand sprayer with distilled water and spray into bottles. A five second spray is sufficient. When completed, remove base and place in lab or equipment room for drying.
5. Caps are placed in a dilute soap solution, scrubbed individually, rinsed in tap water, then rinsed with distilled water and dried.
6. After bottles have dried, select five from the entire set of bottles washed. Cap and send to lab. Each bottle must have a separate lab slip. The Lab of Hygiene receives the bottles and fills them with Milli-Q water. They are then shaken up and analyzed. The constituents analyzed are listed below.

   A. Total Phosphorus
   B. Soluble Phosphorus
   C. Chloride
   D. TS, SS, VSS
   E. Nitrogen Series
   F. Total Lead

II. Manning Automatic Samplers

After every event at all stations where samples were obtained, the following procedures are to be followed.

1. Detach hose from sampler. Attach adapter hose and place orifice into distilled water. Turn selector to "Manual Sample" which will initiate a sampling sequence.

2. When sequence is completed, visually check the clear plastic sample chamber for solids and/or film. If the sample chamber still appears contaminated, then remove chamber and wipe down with a cloth and distilled water.

3. Take a liter of distilled water and pour it into the hose leading into the storm sewer.

4. Once per month at every station, follow procedure II.1, and II.2 as described previously. Use one quart polyethylene bottle for constituents A-E. Total leak should be grabbed in a separate a 250 ml. metals bottle on the site. Save the sample of distilled water and run as a blank. Analyze for:

   A. Total Phosphorus
   B. Soluble Phosphorus
   C. Chloride
   D. TS, SS, VSS
   E. Nitrogen Series
   F. Total Lead

III. Sample Splitter

1. Before initial use, flush with tap water to remove any adhering debris and solids. Visually check all lines and base of splitter chamber for contaminants. Wipe down inside of chamber with cleaning solution (QED II) if dirt or film is apparent.

2. Flush down entire apparatus with two separate 500 ml rinses of distilled and drain.

3. Repeat step 2 for every set of samples. Repeat steps 1 and 2 if samples are especially dirty or oily.

4. Once a month, or every 4th week, after following the above procedure, run one liter of distilled water through splitter, record, and send to Lab of Hygiene for analysis of:

   A. Total Phosphorus
   B. Soluble Phosphorus
   C. Chloride
   D. TS, SS, VSS
   E. Nitrogen Series
   F. Total Lead